THE JOURNAL OF ENGINEERING EDUCATION

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Published by the Society for the Promotion of Engineering Education

Published under the Supervision of the Publication Committee.
H. S. Evans, H. S. Boardman, F. L. Bishop, Editor, University of Pittsburgh.
Published at Prince and Lemon Sts., Lancaster, Pa.

Entered as second-class matter at the Post Office at Lancaster, Pa., under the Act of March 3, 1870.

New Series
Vol. XXII, No. 2. OCTOBER, 1931 Subscription Price, $3.00 per year. Single Copies, 50 cents.

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HISTORICAL SKETCHES OF THE SOCIETY *

By C. FRANK ALLEN,

88 Montview Street, West Roxbury, Mass.

Editor's Note: Professor Allen has been active in the Society since its organization in 1893. He was Secretary in 1895–7; Vice-President in 1898–9; and President in 1903–4; a member of Council since its organization. He was Professor of Railroad Engineering at the Massachusetts Institute of Technology until his retirement from active teaching.

The Society for the Promotion of Engineering Education was not premeditated, it came about. On the occasion of the World's Fair at Chicago in 1893, there was organized an Engineering Congress and Professor Ira O. Baker was a member of the General Committee. Provision was made for a Division E, "Engineering Education." Its special committee was Ira O. Baker, Chairman, Henry T. Eddy, Vice-Chairman, William R. Hoag, Secretary, together with Storm Bull, Mortimer E. Cooley, and Samuel W. Stratton. The program was arranged under the direction of this committee.

When the convention assembled, Professor Baker presided over Division E. Professor Hoag was not present and Professor C. Frank Allen was made Acting Secretary, and served during the entire session.

At the meetings of the Civil, the Mechanical, and Mining Divisions, many of the papers had a preliminary printing and circulation. The division of Engineering Education was without such papers, and engineers interested perforce came to the meeting to see and hear what was doing. It was thought at the time that an advantage resulted.

The papers were well prepared by a list of authors of distinction, and were listened to with interest by those who attended, and the audiences were very satisfactory in number.

The first spirited discussion followed the paper on "Comparison between American and European Methods in Education" and centered largely upon methods of instruction, whether by lecture or by recitation, involving also text-book and laboratory, a subject which was discussed more or less at later meetings.

* This is the first of a series of articles by founders of the Society giving personal reminiscences of individuals and of doings of the Society. F. L. Bishop, *Editor.*

"Graphical Methods," presented by an English professor, also brought out good discussion.

Altogether those who had come together for the final session felt that the subject of Engineering Education should be discussed further and that an organization should be effected for that purpose. Mansfield Merriman, John B. Johnson, and C. Frank Allen were appointed to bring in a Constitution, which they did, coining the name "Society for the Promotion of Engineering Education." However, when this committee also brought in a list of officers, one member arose and inquired if the committee had not exceeded its authority. The present writer mildly suggested that there was no doubt about it; it had. But if a Society was to be organized, it was necessary to act at once; there was no time for other action. It may safely be stated that there are times when a worthy act must be done whether one has the "right" to do it or not. De-Volson Wood was appropriately nominated for President, and John B. Johnson as Secretary. Those who knew Professor Johnson's energy and vim would not question the propriety of his selection. He served for two terms.

George F. Swain was elected President for the next year and his selection of the subject for his presidential address was "The Profession of Engineering Teaching." He valued the teaching side of engineering education as well as the engineering side, and his staff, of which the present writer was a member, was also of his mind as to the desirability of effective teaching.

The present writer was elected Secretary for two years following Professor Johnson. The experience was valuable, if time consuming. He remembers that one member desired to present five different papers. Whether the Secretary had the right to do so or not, he staved him off to one paper. Again when a member who was prolific in discussion amplified his remarks by fifty per cent when they were submitted to him, the Secretary somehow failed to have them printed, whether he had the right to do so or not, the Proceedings were not in the class with the Congressional Record. The writer, while Secretary, adopted the expedient of revising all discussions before sending them for approval. Changing after submission would have been inadmissible.

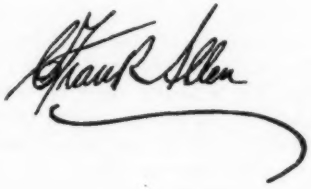
Finance in the Society was no joke in the early days. One expedient adopted was to write to libraries of colleges at which we had members, inquiring if they had copies of our Proceedings. A negative answer may have included hopes of free copies. It happened, however, that our member at that college was urged to stimulate the library to buy copies. The receipts rose from $17.00 to $211.00 and the libraries probably are still buying.

In looking over the list of members in 1893 it was found that

out of a total of about seventy, as many as fourteen afterwards became Presidents of the Society. Five became Presidents of one of the four "Founder" national engineering societies, three of them Honorary Members as well. One became President of the Massachusetts Institute of Technology. Included in the list were members from Canada, England, France, Germany, Switzerland and Russia. The Society had a strong foundation.

The present writer still cherishes the name of Ira O. Baker as the Founder of the Society.

In the earlier periods, the Secretary served for not more than two years, and without salary or honorarium. It was a labor of love. The service, however, was not without profit to the incumbent. The association with officers and members was pleasant and profitable and the experience, for a limited period, broadening. Editing the papers and revising the discussions formed a valuable course in English. The writer remembers an extended research as to the spelling to be adopted, whether per cent. or per cent without the period. General practice, the "style" of printing offices, the spelling in use in dictionaries and encyclopedias left the choice open. With excellent authority to justify it, the Secretary-Editor selected per cent (without the period) as simpler. Again a paper was presented to the Society during the life of an author, who, however, died before the Proceedings were printed. Was the paper posthumous? Nobody seemed to know. The word posthumous was not used. The writer has no regrets that he served a term as Secretary.



SOME ASPECTS OF RESEARCH IN APPLIED PHYSICS *

By HERBERT E. IVES

Electro-Optical Research Director, Bell Telephone Laboratories, New York City

The topic I have chosen, "Research in *Applied Physics,*" may not appear entirely appropriate for a society devoted to engineering education. I have chosen it because of an observation which I have recently heard emphatically endorsed by a group of research physicists. This is that students who have had a good training in engineering are usually exceptionally well equipped for work in laboratories of physics. The most obvious reasons for this turn out to be that their knowledge of mechanical drawing, of the handling of tools, and the manipulation of the slide-rule, give them a big advantage in putting their physics to work in practical problems. The real answer, however, is, I think, somewhat deeper than this. It is not merely that an engineering graduate can do mechanical drawing, or handle a slide-rule, it is because the kind of mind that leads a man to choose engineering is the kind we need in applied physics; and, on top of that, because the mental processes of the engineering graduate are better organized through his familiarity with engineering methods than are those of his colleagues who have had a more theoretical or "purer" contact with physics. My remarks then are based on the assumption that you as teachers of engineering will have passing through your hands a certain number of students who will work for a time, and perhaps for a larger part of their lives, in laboratories such as those of the industries, where physics is to be applied. Some observations therefore on the characteristics of applied physics, the type of men who are fitted for this work, and the nature of the problems which they will encounter, may be of some interest to you.

I would like first to contrast applied physics with theoretical or "pure" research physics. There has been a great deal of exaltation of research for its own sake, research dictated merely by curiosity, and by the desire to extend the bounds of human knowledge. This has at times gone so far as to belittle and condemn research which has a practical end,—as though a research worker who paused to use his knowledge to improve the condition of mankind were soiling his hands. The man who goes into research in

* Presented at the 39th annual meeting, S. P. E. E., Purdue University, June 17–19, 1931.

applied physics must definitely have the opposite point of view. He must rejoice in making things that work. Even so he need not feel that he contributes less to scientific knowledge than if he held aloof from practical applications. Professor Rowland of Johns Hopkins, when a student brought him any new observation, would tell him to "do something to it and see what happens." The slogan of the worker in applied physics should be rather "try to *make use of it*, and see what you find." Now, while much may be learned by a mere simian spirit of curiosity, I believe that fully as much if not more comes out of trying to put a discovery to practical use. We do not really know a phenomenon until we have tried to make it work for us. Not only is the reward of making a phenomenon of nature work for us a material one if success is achieved, but the reciprocal contributions of practical processes to pure and theoretical science are often as great, or greater than those obtained from researches carried out with the sole object of obtaining knowledge. Witness the Edison effect found in the early incandescent lamp, from which has come the science of thermionics.

The demand that some use be made of a physical phenomenon often results in a branch of science being opened up in a way which would have been entirely overlooked if mere curiosity or the verification of scientific theory were the sole aim. For instance in the field of photoelectricity what appeared to be the really fundamental contributions to that subject, such as the light quantum hypotheses, have come entirely from the university and other laboratories of pure science. But such practical problems as the electrical transmission of pictures, television and sound films, have demanded photoelectric cells of greater sensitiveness. So, ingenious and industrious research physicists have been driven to develop photoelectric cells, whose intrinsic sensitiveness and range of response to the spectrum are so much improved as to almost constitute a new class of device.

Another aspect of applied physics which must be realized by anyone devoting himself to it is that very often a practical answer must be obtained to a problem from what must appear to a purist in research as a superficial line of attack. A working answer must be obtained even though the theory is not at all well understood. Industry is full of illustrations of important processes and products in which the art has been developed far ahead of the science. Such developments, often to the chagrin of the formal scientist, have been brought about by intense industry, by the application of special craftsmanship and aptitudes, and by using analogies from other branches of science. Often, working theories of a quite fantastic sort suggested most valuable and productive ex-

periments. An illustration is the carbon microphone, which has been used for nearly fifty years and in millions of telephones without any proved theory of its action being available until quite recently. The fundamental physics and chemistry of photography are not elucidated to this day, but miles of movie film are unrolled before the public everyday despite the lack of a sound theoretical basis. Cases of this sort cannot be sources of any great pride to theoretical research physicists, whose ideal is, of course, that great technical processes and machines should follow in an orderly manner from well organized laboratory research and from application of majestic theories. Such a sequence is indeed more apt to be common in the future, as science becomes more complex and specialized than it has been in the past. Nevertheless the worker in applied physics must always bear in mind that his task is to get an answer in the most direct way as quickly and cheaply as possible even if the solution of his problem demands that he skim over or pass by many of the fundamental and most intriguing questions which are offered by his work. He must cultivate and exercise at all times a special kind of judgment to decide how far he can profitably go along the enticing paths ahead.

It is obvious that work of the sort I have just indicated will appeal much more to some kinds of men than to others. This leads to some remarks on the type of men, among those who pass through your hands, for whom a career in applied physics, say in an industrial research laboratory, is indicated. First of all I would say that a man who is to work in applied physics should be one whose mind is chiefly interested in *things* rather than in *men*. Many of the characteristics which make for success in careers primarily involving human relationships are a positive detriment in applied science. Thus persuasiveness, ability to drive a bargain, a commanding presence, the glad hand, high power salesmanship, skill in bullying a witness, readiness to compromise, tact, diplomacy, are quite wasted in trying to bend nature to our uses. The electrons, protons and photons with which modern physics works cannot be stampeded by any emotional appeal. Instead, stark, straightforward, uncompromising honesty in facing the eternal essentials of a problem is necessary. Indeed for a man to be a success along strictly technical lines, it is probably better for him to have no ambitions toward administrative and executive work. The ideal attitude of mind is perhaps that exhibited by one of my distinguished colleagues. To him a high pressure salesman was endeavoring to sell a course in business management. To clinch his argument the salesman remarked "Of course your ambition is to become the Chief Engineer of your company," to which the reply was "God forbid."

Much emphasis has been placed in recent years on leadership and on organization. Undoubtedly the chief rewards in prestige and in financial remuneration have gone and still go to men who direct and organize the work of others, for the men whose solution of a problem is to pick the proper subordinates and tell them to do the job. There is inherently much less need for executive leadership in research than in most any other branch of activity. Research is pioneering work in which individual genius of necessity supplies the chief driving force. A director of research in a live research group is very apt to be in the position of the French Revolutionary agitator who, upon seeing a mob rush by the restaurant where he was eating, hastily rose from the table, saying "There goes the mob, I must follow them, for I am their leader." The motive power of a research group lies with men who keep contact with and have command over the inanimate material things on which their industry is based. No amount of direction and organization will keep alive a large industry, whose foundations lie in physical science, unless the rank and file are first hand masters of the materials and processes with which they work. Organization, with its charts, budgets, surveys and other machinery, is always in danger of becoming so cumbersome and complicated that it merely keeps its own wheels turning, using up much oil, but with the net result of merely going without friction, and also without doing useful work. The life blood of a research organization feeding an industry is a continual contribution of ideas and projects. Ideas come from individuals, not from organizations, and the most significant and influential ideas in a technical industry often come from below, from individuals who are "thinking with their hands." Hence a supply of such men is vital.

Applied physics is differentiated from unapplied or pure physics by the importance in it of *invention*. There has, I think, been too little honor and credit given of late to invention. Inventors have been looked upon as but little removed from cranks. They have been regarded as decidedly inferior to the more orthodox research worker, who, as has often been said, is revealing the secrets of nature. Inventions are dismissed as "by-products." Actually all our large industries and our present day civilization itself are built upon invention. In fact, the thesis may well be defended that it is by the faculty of invention more than anything else that man is differentiated from animals. In the training given by our university laboratories and engineering schools, great emphasis is given to a study of established methods of doing things, and in methods of investigating how things work, that is, in testing and the accumulation of data and statistics. This latter activity can, however, be entirely sterile. While it is often com-

forting to believe that if we once get all the measurements and data together, the problem will automatically be solved, progress usually hinges on definite acts of invention, that is, some new combination or direction of the facts at hand springing from the minds of specially gifted individuals. Men of the inventive type of mind are among the most valuable of the staffs of our industrial research laboratories, even if often the most disconcerting. I do not know, however, where in university or engineering schools, the technique of invention is studied as a principal subject (if indeed it can be) or where any systematic efforts are made to discover or encourage inventive ability among students. In fact, I have been given to understand that students of the inventive type of mind are nuisances to be discouraged rather than encouraged. It is significant that a noticeably large proportion of such men never complete their college course. It is told of General Sheridan that he got so many demerits for fighting while a cadet as to be disqualified for graduation from West Point. But the authorities of the military academy hazarded the opinion that after all a pugnacious temperament should be a valuable asset in a military career, however troublesome in a cadet, and commissioned him. A similar attitude toward the inventive type of student is advisable.

Now something about the equipment which the prospective worker in applied physics should have. I would like to emphasize the importance of preparation along some lines which are often considered rather menial, and perhaps unworthy of higher education. I refer to a familiarity with and skill in the use of the materials, tools and manipulations by which engineering devices and machines must be constructed. An applied physicist must have a first-hand acquaintance with wood, iron, glass, glue, wax, cement and other shop materials, and with the instruments and devices of the skilled workman. It is the natural progress of any industrial process or machine to originate in a crude model, which nevertheless in its essential parts has the elements of expansion into larger size or into quantity production. Such future development is unlikely to occur if the inventor is not himself a pretty thorough master of materials and shop crafts. He is at a tremendous advantage if he can knock things together with his own hands. An important point is that he must not only have the knowledge of the skilled workman, but he must frequently devise new techniques, often over the protest of the shop employee who has done that kind of thing all his life, for the regular shop worker is not commonly a person of exceptional ingenuity. Many great industrial developments have in fact come from intimate understanding of what can be done with materials which have previously been considered refractory and incompatible. For instance, the devel-

opment of large vacuum tubes for radio and power purposes has been dependent to a remarkable degree upon the invention of methods of making gas-tight seals between metal and glass. The man who has never taken hold of a glass joint before it is cool enough to touch must be ranked as incompletely educated for many phases of work in a modern electrical laboratory.

Turning now to quite a different kind of equipment, there is the matter of mathematical training. The worker in applied physics should have a knowledge of mathematics, to be used primarily as a tool, rather than as a part of his spiritual culture. A thorough knowledge of the more elementary mathematics, such as is attained by a great deal of problem work, is apt to prove of much more value to him than a superficial knowledge of the higher mathematics. The late Lord Rayleigh once remarked that a man could go very far on the rule of three. It is frequently a source of surprise to see how far people of little or no mathematical training can go with merely the guide of a well developed sense of proportion. Conversely it is sometimes appalling to see how a glib facility with mathematics can coexist with remarkable obtuseness to simple and essential physical considerations. A research worker should, of course, know of the possibilities of higher mathematics, but it may be suggested that he will profit more by a very thorough drilling in the more elementary forms, supplemented by what might be called a survey course on the subject matter of higher mathematics, than by an unsuccessful attempt to make him proficient in the advanced forms.

When the graduate of an engineering school goes into a physical research laboratory, it is important that he should recognize and be prepared to reconcile himself to certain conditions and limitations on his activities, and to certain personal responsibilities. For one thing, he must realize that all big things are in their beginnings small. This fact imposes certain obstacles to his activities and imposes on him certain responsibilities. Since it is impossible for anyone to foresee with certainty how important a line of work will be at the period of its initiation, new work is apt to start with limited facilities and support. While it is commonly said that the day of the garret inventor is passed, it is nevertheless true that in even the largest industrial laboratories, there are usually, and ought to be, a number of investigations going on whose future is so obscure that the best they can hope for in their early stages is the equivalent of a garret or cellar. (Faraday worked in a cellar, so that no scientist should feel cast down if that is all he has.) The man who is assigned to such an obscure job has many of the personal problems of the proverbial lone hand inventor. He needs the enthusiasm and faith in his job which is

characteristic of the individual inventor. He must work on his problem largely as an individual. His facilities are apt to be relatively meager, calling for ingenuity and resourcefulness on his part to enable him to carry on. He must expect to have to sell his work to his employers,—to convince them that it warrants further expenditure of money and effort. He is very apt, like the individual experimenter, to underestimate greatly the time and money that will be necessary to bring his work to perfection. It is his responsibility to be able to recognize a baby of promise. On the other hand, he must know that applied science is working at all times under the shadow of the law of diminishing returns. A worker in *pure* science does not, in general, have to ask the question whether the return warrants the expenditure of time and money incident to the investigation. In the democracy of pure science, one established scientific fact is, in general, as valuable, or stands a chance of being as valuable, sometime, as any other. In applied science, contrary to the very common belief, discoveries and inventions of the most spectacular sort are frequently too expensive or yield too little return in actual service value to warrant application and commercialization; at any rate at a particular time.

A man prominently identified with the development of the automobile recently wrote an interesting article under the title "It Does Not Pay to Pioneer." The point to his remarks was that the real pioneering work on which big industries are founded is very frequently indeed done a generation or so before the time is ripe for the art to be commercially developed. The upward road of applied science is strewn with the wrecks of developments which have been doomed by premature exploitation and the law of diminishing returns. It is pioneering work of this sort, in advance of its time, that the industrial research laboratory must avoid. The director of research work, and the individual workers, must recognize that, however scientifically attractive certain problems may be, and however much glamour there may appear in their solution, many such must wait upon the general advance of science, or for a change in social conditions.

These considerations, which must sober the worker in applied physics, are largely dominated by the time factor. Many projects must be laid aside and nursed, and many things which appear merely fantastic at one time later become feasible. In the long run, there is a wide belief (particularly among the contributors to the popular scientific magazines) that the public will, sometime, enjoy practically every wildest Arabian Nights dream of applied science. We are being urged to become a race of button pressers, with countless mechanical slaves to save us from all fatiguing labor, and ultimately to give us unlimited leisure. This brings up

another observation in regard to the training of engineers. What to do with this leisure that lies before us, has become a major educational and social problem. One answer appears to be that we shall have more opportunity in our lives to enjoy things of beauty, that is, inventions of various sorts which appeal to the senses and idealize life. The study of the esthetic side of existence used to receive little attention in engineering schools. Should not the future engineer be exposed more than he has been to some of the fundamental forms of the fine arts, such as music, sculpture, and the drama? Those of us who saw talking motion pictures in the laboratory stage, even after the engineering technique was largely perfected, know what sad things those were. The scenarios were conceived by engineers, the dialogue was written like an engineering report, and the photography was according to the best practice of the blueprint room. It took the touch of the artist to reveal the possibilities of one of the newest and most flexible of the arts. Looking toward the work which the engineer will have to do in the future, it seems probable that a greater acquaintance with the esthetic applications of science will be called for.

Let me now conclude my remarks on "applied physics" by roughly summarizing the characteristics which should indicate to you which of your students are fitted to go into the industrial physical research laboratory. The worker in applied physics should be a man interested primarily in *things*. He should have an understanding of materials and crafts. He should have inventive ability, ingenuity and resourcefulness. He must have creative imagination. Nevertheless he will not escape from the necessity of keeping his imagination tempered with judgment. He must have the same ability to adjust his own work to the economic conditions of the industry in which he works that make for success in any other branch of activity. Men fitting into this classification will not be passing through your hands in large numbers, but the need for them is great, and we bespeak for them your sympathetic consideration.

COÖPERATIVE ENGINEERING RESEARCH *

By A. A. POTTER,

Dean of Engineering, Purdue University

Research and Development.—Research has as its aim the discovery of something hitherto unknown by the employment of scientific methods. Engineering research has as its objective the development by *scientific means* of new manufactured products, more efficient machines or tools, special mechanisms, improved devices, reliable meters or instruments, better manufacturing processes, or more economical methods of operating equipment.

No very clear line can be drawn between pure scientific and engineering research, although the latter is more generally concerned with results of immediate economic value. The difference between development and research is also not always distinct. Both research and development may involve much "cut and try" effort. Development is usually the product of research or may follow it if a successful product is the aim. Laboratories of research and development are now taking the place of chance discoveries by inventors.

Coöperative Research.—As industry is the best medium through which the results of engineering research are utilized, there is a constantly increasing amount of research which is carried on by American industry in coöperation with educational institutions, special research foundations and Government bureaus.

In the past there had always existed a definite gap between the successful completion of a scientific research project and the utilization by industry of the results secured. This gap is being greatly reduced by coöperative research which brings together most effectively the talents of the scientist and of industry.

Research Agencies.—Engineering research in the United States of America is carried on in industrial laboratories, by commercial testing organizations, by engineering societies, in special research institutes, by Government bureaus and departments, and by engineering colleges.

Examples of industrial research laboratories are those of the Bell System, the General Electric Company and the Westinghouse Electric and Manufacturing Company. Of the special research in-

* Presented at the 39th annual meeting, Purdue University, June 17–19, 1931.

stitutes the Mellon Institute of Industrial Research at Pittsburgh is the pioneer and leader in coöperative research. The industrial research of this institute is organized on a contract basis, the problem being set by a person, firm or association interested in its solution and no contract is accepted for less than one year. The investigations are carried on by holders of Industrial Fellowships who are engaged by the Mellon Institute out of funds contributed by the coöperating agencies or donors while the results obtained by the Institute belong exclusively to the donor of the Industrial Fellowship. The Mellon Institute has successfully demonstrated to American Industry, irrespective of size, that coöperative research is profitable.

Several of the national engineering societies are carrying on research through standing committees. Thus the American Society of Mechanical Engineers has expended from its own funds since 1921 about $77,000 in organization, development and other research activities, and the success of its efforts is attested by the fact that during the same period American industry has contributed over $250,000 and the Engineering Foundation over $12,000 for investigations under the direction of the A. S. M. E. Main Research Committee.

The U. S. Bureau of Standards is an example of successful cooperation between a Government bureau and American industry.

The major advantages to industry of coöperative research at carefully selected educational institutions may be summed up as follows:

1. The college or university atmosphere is sympathetic to research.
2. There are specialists available who can furnish basic scientific knowledge.
3. There are special laboratory and library facilities not ordinarily found in any except the largest industries.
4. There are means for wider and more prompt publication of results.
5. There is at hand skilled direction of research at relatively low cost.
6. The cost of research at educational institutions may be ordinarily carried on at a lower cost than is possible in an industrial laboratory.
7. Research at colleges will insure a supply of engineers who have the training to create new knowledge.
8. There will be an improvement in the quality of the engineering graduates, as students as well as teachers are brought in contact with new and practical problems.

Engineering colleges are benefited from research in coöperation with industry by:

(1) Their teachers and students have contact with research projects and so with trends in practice.

(2) Teachers are afforded an opportunity to devote part time in studying new truths.

(3) There is a possibility of interesting students in creating new knowledge through research.

(4) Improved facilities become available for graduate and undergraduate study.

(5) There are additional opportunities for services of benefit to the public.

Research in Engineering Colleges.—Individual manufacturers and particularly small industries have been served rather generally by engineering colleges through special tests and investigations of their product. These have been mainly performance or service tests of routine character which required little original scientific investigation. Until recent years American industry in general and the larger industries in particular have given too little encouragement to research at engineering colleges. If industry desires engineering college graduates with the ability to extend the frontiers of knowledge it will have to aid the engineering colleges in bringing their students into contact with teachers and investigators who are constantly working on the solution of new problems. While some of the larger industries may be able to solve many of their problems in their own laboratories, they must realize that they are dependent upon colleges and universities to find and to develop their research staffs.

The Supplement to the Journal of Engineering Education published in February, 1931, records the status of engineering research in the colleges and universities of North America. Leaving out the Mellon Institute of Industrial Research, the engineering colleges of the U. S. A. received $1,225,570 for research during 1928–29 from outside sources; $668,853 from institutional funds and 262,440 by legislative appropriation. This made a total for the year 1928–29 of $2,156,863 and provided for the employment of 575 full time and 807 part time research workers.

The Utilities Research Commission.—The Utilities Research Commission of Chicago is an example of an agency which has been most sucessful in developing coöperative research mainly at engineering colleges. This Commission is sponsored by six public utilities and started it activities in 1924 on five projects with a budget of $25,000. In 1930 the Utilities Research Commission expended $190,000 on active projects carried on at the University of Illinois, University of Michigan, University of Chicago, Johns Hopkins University, Massachusetts Institute of Technology, Purdue University, Batelle Memorial Institute, the U. S. Bureau of Standards, the

Peoples Gas, Light and Coke Company of Chicago, and in connection with National Associations. The Utilities Research Commission, instead of building a research laboratory of its own, utilizes the laboratories and research staffs of educational institutions and of other research agencies. By this means the Commission is providing improved facilities for the training of students in scientific research of practical value to industry. The projects being investigated include production and transmission of electric power, utilization of gas, transportation and ice manufacture, as well as fundamental scientific problems. The method used by the Utilities Research Commission in assigning and in following up research projects follows:

Projects for investigation are usually suggested by the companies which contribute to the budget of the Utilities Research Commission, but in some cases by sources outside of the Commission. The colleges and other agencies, which are at present cooperating with the Commission, are also invited to submit new research problems to the Director for the consideration of the Commission. When the Commission decides to investigate a project it is given a "case number" and a "case committee' of three or more members who are appointed from the type of utility in the immediate field of which the research falls, with additional members from other fields represented by the Commission. The Commission, which is acquainted with the facilities of the educational institutions and of the other research agencies, then places the problem before some college or other research organization and invites a proposal which must include tentative methods of procedure in conducting the investigation, a statement of the present facilities available at the institution, an estimate of the length of time required to complete the study, and a detailed estimate of cost for salaries, equipment, supplies, and overhead. If the proposal appears reasonable to the Commission a contract is closed with the coöperating agency and the estimated budget for the first quarter is paid in advance. The agency which coöperates with the Utilities Research Commission designates from its staff members a director for each case or project. This case director and his associates hold frequent meetings with the Case Committee of the Commission which acts in an advisory capacity and its chairman is the spokesman before the Commission on matters pertaining to the problem under investigation. The Director of the Commission also visits each project at frequent intervals and keeps the coöperating agency fully informed of the policies of the Commission.

The coöperating research agency submits to the Commission quarterly reports of progress describing the studies made and summarizing the results secured. In some projects, monthly as well as

quarterly reports are submitted. Near the end of each quarter the coöperating research agency submits to the Commission a detailed statement of expenditures for salaries, equipment, supplies, overhead and other expenses, together with an estimate of the needs for the next quarter.

Coöperative Research at Purdue University.—Coöperative research at Purdue University was started in the early eighteen nineties by the late Dean W. F. M. Goss, who installed the first test locomotive in the world and who greatly aided the railroads in standardizing and improving their mechanical equipment. Cooperation between Purdue University and the American railroads has continued since that time and has involved a great variety of investigations on brake shoes, superheaters, air brakes, locomotives, car wheels, car couplers, draft gears, front ends, etc. Coöperation between the American Railway Association and the Engineering Experiment Station of Purdue University was started in 1925 with the investigation of power air brakes. This included laboratory tests as well as road tests, involved a full time research staff of 55 to 80 and an expenditure of over $200,000 per year. Other projects now under way in coöperation with the American Railway Association are draft gears, tank cars, and train connectors. The coöperative investigation on draft gears is carried on in a manner similar to that used in connection with the cases for the Utilities Research Commission. The Engineering Experiment Station of Purdue University is directly responsible for the conduct of the investigation as well as for the results secured, but is aided by a committee of the American Railway Association in handling the details so that the results are of value to the railroads as well as to the manufacturers of draft gears. In the case of the investigations on air brakes and train connectors the plan is somewhat different. The Engineering Experiment Station provides space and staff, and aids in the conduct of the tests but the Director of Research for the American Railway Association is responsible to that association for the detailed procedure and for the results secured.

For nearly eight years the Purdue University Engineering Experiment Station has coöperated with the Indiana Limestone interests in a study of staining and efflorescence of Indiana limestone. A by-product of this investigation was a patching cement for limestone.

The Utilities Research Commission of Chicago is coöperating with the Purdue University Engineering Experiment Station in three studies, designated as: Case 12—Lightning Protection for Transformer Secondaries; Case 17—Iron and Steel Welding with Manufactured Gas (a by-product of this is several new torches for which patent applications are now pending); and Case 28—

Weatherproof Covering for Line Wires. It is also coöperating with the Agricultural Experiment Station of Purdue University in a study of the Acceleration of Plant Growth by Electrical Illumination, which is designated as Case 36 of the Commission.

The invention of a Cathode-Ray Oscillograph by a member of the electrical section of the Purdue University Engineering Experiment Station has been followed by several investigations in cooperation with manufacturers and electric utilities, the most important of which are the Detroit Edison Company and the Consumers Power Company of Michigan, the Electric Service Supplies Company of Philadelphia, and the studies of television for the Grigsby-Grunow Company of Chicago.

The Indiana Gas Association has been contributing to the Engineering Experiment Station for the past four years $10,000 per year for a study of gas utilization with particular reference to residence heating.

During the past five years the Indiana coal interests have cooperated with the Engineering Experiment Station in studies of Indiana coal for power generation and for use in connection with small stokers.

The American Society of Heating and Ventilating Engineers has been coöperating with the Engineering Experiment Station since 1927 in a study of the performance of house radiators, while the American Society of Mechanical Engineers, through its Main Research Committee is aiding in a study of steam boilers working at pressures up to 3,500 pounds.

In highway and structural engineering the Engineering Experiment Station of Purdue University has had in recent years several coöperative projects, the most prominent of these being: Investigation of Road Slabs, Fatigue of Concrete, Warped Beams, and Ball Test Applied to Mortar and Concrete, all in coöperation with the U. S. Office of Public Roads. The Indiana Sand and Gravel Association has coöperated in studies of Concrete as Affected by the Quality of Aggregate. Thomas E. Currie Co., of Detroit, has also coöperated in an investigation of concrete.

The above is a partial list of the coöperative projects conducted in the Engineering Experiment Station of Purdue University. The growth of interest on the part of industry in engineering research is evident from the fact that from a very small beginning in 1920–21 the income of the Purdue University Engineering Experiment Station from coöperative investigations was increased to 119,146.98 in 1925–26, to $243,897.90 in 1927–28, and to $301,754.42 in 1929–30.

The procedure for handling coöperative projects in the Engineering Experiment Station of Purdue University follows:

The Director of the Engineering Experiment Station who is also Dean of the Schools of Engineering, is held responsible by the President and Board of Trustees for the proper conduct of all engineering research. When a research problem comes to Purdue University the Director of the Engineering Experiment Station assigns it to the division or divisions best qualified by staff and equipment to handle the project. These divisions corrrespond to the major engineering curricula taught at Purdue University. Thus, electrical problems are referred to the Head of the Electrical Engineering School, civil to the Head of the Civil Engineering School, mechanical to the Head of the Mechanical Engineering School, and chemical to the Head of the Chemical Engineering School. Departments such as chemistry, physics, mathematics, biology, shop practice, etc., coöperate as needed. The head of the school in consultation with the director sets up an organization for the project and prepares estimates with reference to expenditures.

A twenty per cent overhead charge is usually made in connection with projects carried on in coöperation with industries and public utilities. No overhead charge is made when investigations are carried on in coöperation with National Engineering Societies.

The contract is drawn up so that in most cases the results may be published by Purdue University but the coöperating agency is given an opportunity to review the manuscript and to make suggestions about the material to be included. In certain investigations the results are kept confidential until the findings are properly protected by patents.

Quarterly reports are submitted to the Director on all projects, who in turn transmits such reports to the donor or donors. The Secretary of the Engineering Experiment Station, who is also professor in charge of Engineering Extension, is responsible for the uniformity of reports and of publications. Monthly financial statements are sent from the office of the Director to the heads of schools.

Purdue University has always had a very liberal policy with reference to inventions by its staff members. To insure full encouragement and adequate reward for creative work the Purdue Research Foundation was recently created as an organization outside of State control, but clearly affiliated with Purdue University. Its president is the President of Purdue University and, while it does not interfere with the Engineering Experiment Station or with researches of Purdue University staff members, it stands ready to handle all patent matters as well as development problems which may result from the research activities of Purdue University.

The results secured by industry through coöperative investigations at the University of Illinois, the University of Michigan, the

Massachusetts Institute of Technology, Ohio State University, University of Wisconsin, Johns Hopkins University, Cornell University, Purdue University, and at several other engineering colleges indicate that such institutions can undertake and carry out successfully research projects of any magnitude. Engineering societies, trade associations, public utilities, and industries (*both small and large*) will find that money invested in research, at carefully selected engineering colleges, will pay large dividends not only in practical results secured but also in increasing the supply of engineers and scientists who have the training to extend the frontiers of useful knowledge.

THE ADMINISTRATION OF ENGINEERING RESEARCH ACTIVITIES *

By A. E. WHITE

Director of the Department of Engineering Research, University of Michigan, Ann Arbor, Michigan

Two former members of a university faculty recently made some interesting comments on engineering research at universities. The first stated that, with a competent and energetic director, a department of research might grow to the limits of the director's capacity to direct and supervise personally the various problems which came to the institution, but that it could not grow much beyond. He divided all members of university faculties, from the standpoint of ability to serve an activity like an engineering research department, into three groups. The first group consisted of outstanding men eminently fitted to conduct and direct research, whose ability had been recognized outside of the University. These men, he maintained, would not be willing to work through university research organizations. The second group consisted of men of mediocre ability who lacked initiative and aggressiveness, but who would do, with a fair degree of competence, such work as was brought to them. To his third group were relegated those individuals who, from lack of training in fundamentals, or lack of natural ability, or lack of inclination, possessed no possibilities as research men.

The other former faculty man maintained that engineering research could not be conducted in connection with our universities to any significant extent because those sponsoring such research could not be assured of adequate protection of any of the findings that might result.

If the comments of these two men indicate nothing more, they at least point out that if any engineering research department suceeds, it suceeds because of a full and frank appreciation of the many difficulties which have to be met and solved, and because of the initiation and following through of a constructive program.

No engineering research department can ultimately succeed unless it receives sympathetic consideration of its problems and needs from the administrative officers of the institution with which it is

* Presented at the 39th annual meeting, S. P. E. E., Purdue University, June 17–19, 1931.

connected. It is not too much to ask those charged with the final determination of the policies of such a department to give consideration to its needs at least once every three months. Andrew W. Mellon, Secretary of the Treasury of the United States, and his brother, Richard B. Mellon, President of the Mellon National Bank, meet frequently with Dr. Edward R. Weidlein, Director of Mellon Institute, for the purpose of conferring and advising with him regarding the solution of the various problems which arise in the administration of the Institute. The administrative officers of a research organization should be more than figure heads; more than a mere body of review for passing judgment upon the decisions of the director. They should engender enthusiasm and make constructive suggestions for the expansion of the department's activities.

Before any great progress can be made in engineering research, several matters of policy must receive consideration. The first, and possibly the most important of these, is the character of the problems which should be accepted. All problems may be classified as of three kinds: those of a routine nature; those of applied research; and those of fundamental research. An engineering research department, in its infancy, may be called upon, and may find it necessary, to accept work of a routine character. At the start, the refusal of work of this type might mean the permanent severing of relations with some industrial organizations. No harm, at least, is done, and much good may result from the acceptance of work of this type. After a research organization has been in existence for some time, however, and has had an opportunity to establish more or less of a reputation for itself, it is doubtful if it should then accept work of a routine character, except as a matter of courtesy, or when facilities for doing the work elsewhere are not readily available.

The work in applied research will doubtless prove to be the most fruitful for a research organization. Such work will include the major number of problems received, and will be the activity through which the department can create good will among the manufacturing and industrial interests which it serves.

The third type of work, fundamental research, is one for which a department, from time to time, may get outside financial assistance, and one which it may be able to support to a degree from funds at its disposal. The department should at all times be sympathetic toward fundamental research and should do everything possible to encourage work in this field, whether the encouragement be in the nature of enthusiastic interest or financial grants.

The patent problem is the present outstanding bogey in the expansion of engineering research activities from outside grants.

No generally accepted policy has been adopted by the various engineering research departments in the country. Most directors will advise prospective clients that the patent matter is not especially vital; that, if anything of a patentable nature does develop, the matter will be worked out amicably. This is not a satisfactory answer to an executive who is accustomed to being informed as to just what can, and what cannot be done. Patents are, no doubt, for the most part "straw men." Yet, when the placing of a research contract is before an executive, these "straw men" become "men of strength," for any indefiniteness regarding the disposition of possible patents may prove to be a very real obstacle.

I shall not take the time to present the methods which other engineering research departments have taken to meet this difficulty. I shall merely set forth the procedure at the University of Michigan.

At this institution, four options are possible in the administration of patents which grow out of work administered by the Department of Engineering Research. Under Option A the client can obtain full control of the patent. He does this by paying a service charge of a very substantial nature, which is greatly in excess of the normal service charge, which will be discussed later. Option B gives him the use of any patent or patents resulting from the work which he is sponsoring, at no increase in service charge, and with the payment of no royalty or license fee. This option places the patent or patents with a trustee for administration. Those other than the client who wish to secure rights may obtain them by the payment of royalties or license fees, 50 per cent of which is made available to the client, 25 per cent to the University, and the other 25 per cent to the inventor.

If a client does not wish to exercise either Option A or Option B, the University reserves the right under Option C to take out patents, although with the understanding that the client may have the use of the patents at no royalty or license fee. If the University should take out patents, it would undoubtedly have them administered by a trustee. If thus trusteed, 50 per cent of all royalties received would accrue to the University and 50 per cent to the inventor. The writer is not sure that it would be advisable for the University to exercise this option, for patents are at the same time both assets and liabilities. It is felt, however, that such an option should remain in the contract entered into with the client.

A fourth alternative, Option D, is provided in case neither the client nor the University is desirous of exercising the options just mentioned. Under this option the inventor is at liberty to take out the patent and administer it as he sees fit, with the only proviso that the client may have the use of it at no royalty or license fee.

Up to the past few years, the grants made to universities for industrial research were relatively small. Little work of value resulted, and the clients looked upon these grants more from a philanthropic than from a business standpoint. The size of the grants in recent years made to many of our engineering research departments has increased considerably and such grants have carried with them an obligation on the part of the departments to produce results of value. This obligation has, for the most part, been met and the result has justified the increased grants. Greater and greater demands have, in consequence, been made upon the facilities of the educational institutions doing research so that it has become recognized as sound business policy to make nominal service, or overhead, charges. There is thus far no established uniform rate among the different universities for such service charges, although the time may come when this may be desirable. Some departments make no overhead charges. Some are so anxious to obtain research grants that they agree to provide a portion of the expense. Such procedure may be quite proper if viewed as a coöperative activity in which all of the findings are made available to the world at large. Also, work, sponsored or supported by national engineering organizations or foundations, or by grants made available with no thought of material return may very properly be administered without a service charge.

Yet, when a service charge is viewed as reimbursement for the use of light, heat, power and floor space and for clerical, accounting and administrative expenses, the justification for such a charge is fully appreciated. In fact, this charge, even now, in all institutions of which the writer is aware, is so small as to fail to meet adequately these costs.

The service charges at the University of Michigan in the past have been at the rate of 30 per cent on personnel, or 150 per cent on personnel provided a patent results and the client wishes the assignment of it to himself. Beginning with July 1 of the present year, however, the service charge will be changed to 20 per cent. This will be on the entire cost, with a 100-per-cent service charge if a patent results and the client desires full assignment to himself. Strange as it may seem, there will be little difference in the service charge income whether it be figured on a 30-per-cent basis on personnel or a 20-per-cent basis on the entire cost. The latter method, however, involves simpler bookkeeping and is less confusing to the client.

The present organization of the Department of Engineering Research at the University of Michigan has, of course, developed with the growth of the research activities. It is, of course, a definitely recognized department in the Colleges of Engineering

and Architecture and, as such, its Director reports to the Dean of these colleges.

By action of the Board of Regents, early in the development of the Department, an Administrative Committee, composed of the Dean of the Colleges of Engineering and Architecture, the Director of the Department of Engineering Research, and seven department heads in the College, was appointed. The function of this committee is to consider matters of policy in connection with the Department, and, when necessary, to bring these matters to the attention of the Board of Regents.

Further, it has been necessary to refer so many matters to the attention of the administrative officers of the University that the Board of Regents appointed a Committee on the Department of Engineering Research, consisting of the President, the Vice President and the Secretary, and two members of the Board of Regents. This is essentially an executive committee of the Board of Regents for the consideration of matters requiring regential action by the Board.

Recently it has been found expedient to appoint a smaller committee, known as the Policy Committee. This is, in effect, an executive committee which considers certain matters of policy and procedure, and transmits recommendations, when feasible, to the Administrative Committee. This Policy Committee is composed of the Dean of the Colleges of Engineering and Architecture, the Director of the Department of Engineering Research and the heads of three departments.

Likewise, a Financial Control Committee, composed of the Dean, the Director, and two department heads, meets at frequent intervals for the purpose of passing upon proposed expenditures of over $100 from the funds of the Department.

The Administrative Staff of the Department of Engineering Research consists of a full-time director, an assistant director, two assistants to the director, and department heads as directors of research in their respective departments.

Possibly one of the reasons why engineering research activities in many institutions have not grown more than they have is that they do not have a full-time directing administrative staff. It is quite customary in many schools for a dean to act, not only as head of a department of instruction, but also as head of the department of engineering research. This type of organization may be quite satisfactory, provided there is someone under the dean who gives his full time to the administration of the activities of the research department. Where the department is not under the direction of an individual who devotes his full time to it, one seldom finds appreciable progress or development in engineering research activities.

The Assistant Director is charged with the review of the various projects under investigation. It is his responsibility to see that the client is given monthly reports on findings and finances, and that progress reports are furnished to the client as occasion may require. He can, of course, assume no responsibility for the nature and text of the information forwarded as that must be the responsibility of the one who is in charge of the work.

Of the two Assistants to the Director, one devotes his time and attention to procuring new research projects, and the other to serving virtually as office manager and supervising matters of a financial and accounting character.

Beginning on July 1, 1931, the heads of the various departments at Michigan wherein engineering research work is in progress will be asked to serve as directors of research in their respective fields. This step is for the purpose of keeping the department heads in closer touch with the research work in their individual departments, of enlisting their interest in procuring further research projects, and of providing them with authority for the general supervision of the work in their particular field.

Members of the faculty are used on research problems for technical direction, in an advisory capacity, or for the performance of actual technical work. Practically every project being administered by the Department is under the technical direction of a member of the faculty. These men may have assistants on either a full- or part-time basis, or may do all the work themselves. In addition to the faculty members used in technical direction, a member of the English staff, as Editor of Publications, is employed part time for editing and supervising the publication of technical bulletins, circulars, and reprints by members of the investigational staff. Also, another member of the English staff, as Assistant Editor, devotes a considerable portion of his time to the supervision of reports from the standpoint of form and English.

The full-time investigational staff in the Department consists of research engineers, research physicists, research chemists, research associates, and assistants. These men, in many cases, work under some member of the faculty who is engaged in the direction of the problem, although in some cases they work independently of this direction. Part-time help is also required. Preference is given to graduate students for the part-time positions, although some of the students employed are still under-graduates.

A considerable clerical and stenographic staff is required to take care of the preparation of reports and bibliographies, as well as matters of an administrative and business nature.

Mention must also be made of the mechanics and instrument-shop workers who are employed, for many of the research prob-

lems require special equipment, and in such cases the investigator must turn to an instrument shop for assistance.

During the past year, the Department of Engineering Research at the University of Michigan required the full- or part-time services of 313 persons. These were divided as follows:

1 director
1 assistant director
2 assistants to the director
49 members of the faculty
46 persons with the equivalent rank of assistant, research associate, research engineer, research physicist, or research chemist
7 fellows
23 clerks and stenographers
14 mechanics
170 students, of which number 58 were registered in the Graduate School and 53 were registered for advanced degrees.

All of the employees listed above were not, to be sure, on a full-time basis. Neither were there 23 clerks and stenographers permanently on the staff. This number represents the turn-over, as well as the permanent employees.

Considerable attention has been given to the matter of keeping the Research Department in close touch with the client. This is of primary importance. In fact, one director of a research commission placing work at various institutions in the country has divided them into three groups. One represents the type in which there is a willingness to approach problems from a standpoint mutually acceptable to the client and to the university; the second type includes those institutions willing to accept problems suggested by the client, although unwilling to receive, to any appreciable extent, suggestions as to how the work is to be done; the third group consists of those institutions which are willing to receive money or financial support from the client, but which are unwilling to grant to the client any voice in the solution of the problems.

For the purpose of doing everything possible to keep the client frequently and coöperatively informed, a strong effort is made at the University of Michigan to see that every person directing a research project is in personal contact with the client at least once a month, and that, in addition, finding reports are transmitted to the client monthly. A typical monthly finding report is given below:

Project No. XYZ Work Report for the Month of April, 1931
For ABC Company
On Permeability to Various Gases of Alloy Retorts

WORK IN PROGRESS DURING THE MONTH

The work on the effect of hydrogen sulphide on various alloys was continued.

Samples of nichrome heated 750 hours in screw stock turnings were examined. It was found that a very small amount of sulphur had been absorbed. Nichrome samples were heated 750 hours in screw stock turnings and carburizer, but have not been examined metallographically.

The test being run in air on good and poor nichrome specimens from the section of failed retort was discontinued after 1050 hours, and another started using an atmosphere of air containing 2.5% sulphur dioxide. At the end of the test in air the samples of unsound material were badly attacked in places, and one was cracked. The good samples showed little evidence of local attack.

Analysis of the barium carbonate samples exposed to sulphur dioxide indicated that very little sulphide was present, and also that there was some carbonate remaining.

WORK IN PROSPECT

The work on the scaling of heat-resistant alloys in sulphur-containing atmospheres is to be continued.

Samples of Armco Iron and "18–8" alloy are to be exposed in screw stock turnings.

The absorption of sulphur by sodium carbonate will be investigated.

The effect of copper on Duraloy and on a silicon-containing alloy is to be studied.

(Signed) _____

Progress reports are also sent to the client from time to time, as the work may warrant. Likewise, upon the completion of any project a final report is prepared. The monthly report is purposely made brief so that a busy executive may feel inclined to look it over immediately upon receiving it. It is appreciated that those who give final approval to a research program are accustomed to having information reduced to the barest lucid statement possible, and will give attention and consideration to a short, concise statement when they would not be inclined to review the findings in all of their various ramifications. Every attempt is made to make the reports complete with full data incorporated. They are so arranged, however, that one can get the object and the general findings without reading the entire report.

Within the past year steps have been taken at the University of Michigan to furnish every investigator with a monthly financial statement. At the beginning of an investigation he is usually informed as to the total amount made available, but without a monthly financial statement he is not apt to realize the rate at which funds are being expended. This statement is furnished to

the client also when it is desired. This policy has been found extremely helpful and its discontinuance would meet with strong protests from both the investigators and those sponsoring work. A typical financial statement follows:

Name of Supervisor

DEPARTMENT OF ENGINEERING RESEARCH
UNIVERSITY OF MICHIGAN
ANN ARBOR

PROJECT NO. 999
FOR: ABC Company
ON: Xyz Study

APPROPRIATION		
Period: June 1, 1930, to June 1, 1931 Amount.....		$10,000.00
Authorization: Contract, A, 6/6/30		
EXPENDITURES		
During April:		
Personnel	$478.39	
Stenographic Charges (Reports)..	.53	
Service Charge *30%*	143.68	
Materials, Supplies & Apparatus..	23.40	
Travel	200.88	
Total during April	$846.88	
Total, June 1, 1930, to April 30, 1931	$8,190.03	
OBLIGATIONS, EXCLUSIVE OF PERSONNEL AND SERVICE CHARGES, i.e., orders outstanding April 30, 1931, per attached statement, *estimated*....	$ 320.65	
		$ 8,510.68
BALANCE, *April 30, 1931*		$ 1,489.32
to cover to June 1, 1931		
Personnel		
Stenographic Charges (Reports)		
Bibliographer's Services		
Eng. Res. Analytical Laboratory		
Universal Test Engine Tests		
Service Charge		
Travel		
New Orders		

The principles of success for an engineering research department are relatively few. One of great importance is that the activities be put on a business basis and that the administration of

research be viewed as a business proposition quite as much as any other type of activity. Where work in this field has not gone well, there is a strong possibility that the trouble has been due to the fact that it has not been viewed as a matter of business; no one has been exclusively charged with its success.

It is also evident that those who are charged with the direction of the various research projects can neither make nor break the department. No member of the faculty should accept work for its monetary return only. Acceptance under this condition does not imply whole-hearted, enthusiastic interest. Nor should one accept when he is likely to be prevented by other duties from giving the work the necessary time, or when he is not able to make it his main interest when and while engaged in the investigation. In other words, if an investigator enters into a program with indifference, he will tend to render service that is unsatisfactory to his client, detrimental to the reputation of the investigator, and injurious to the University's reputation as a research center.

As I look back, however, over my experience of the past few years as the director of a research department, I find, on the whole, that those who have been charged with the direction of investigations have entered into the work enthusiastically, and, when they have worked on the problems in the times set aside for that work, they have concentrated upon them and carried them forward as if that were their one main interest.

In conclusion, the experience of the Department of Engineering Research at the University of Michigan has shown that engineering research activities of value are possible in an educational institution, and that those activities can develop, doubtless to limits beyond our present dreams. It is believed that the success already attained, and the larger, fuller success which is the goal of every department of engineering research are dependent upon a few fundamental principles. These principles, as has been pointed out, are sympathetic and enthusiastic coöperation of the administrative officers of the institution involved; a fearless and frank facing of certain matters of policy, such as the character of problems to be undertaken, patents, and the overhead charge; the careful working out of a simple, but business-like administrative organization; the cultivation of the true research spirit among the members of the faculty and those composing the technical staff; and last, but by no means least, the development and maintenance of a friendly, coöperative contact with the client.

Discussion

D. C. Jackson, Jr. (University of Kansas): There was a very well organized scheme of administration outlined, and Director

White stated they received excellent coöperation from the instruction staff on the research work.

It impressed me from this overhead administration, a separate research department, that it might be rather difficult to encourage research work in the teaching staff, and I would like to ask Director White just how they get that really effective coöperation from the instruction staff.

A. E. White (University of Michigan): I think Professor Jackson has raised a question to which it is difficult to make a specific answer.

Coöperation, of course, is always a two-party proposition. In this case the two parties are those in charge of administration and the investigators themselves. It is well recognized that as much freedom as possible must be given to the investigators, but these investigators must also recognize the service rendered by administration. I quite agree with Dr. Ives' statement to the effect that the more you can give the research men absolutely a free hand, and keep the administrative machinery with regard to work in the background, at least so they are not aware of it, the smoother things will run.

I do not think we have absolutely succeeded in solving the problem which has been raised as to getting coöperation from the departments. We have solved it, I think, from the standpoint of getting coöperation, but I do not think the problem has yet been completely solved from the standpoint of stimulating every man in every department to his utmost.

If, however, we have succeeded in any way, it is due to the fact that we have endeavored to give every research man as much liberty as possible. We have essentially confined him with very few restrictions. We have told him when a research project comes in, it is to be worked out to the amount which is granted. We ask him for brief monthly reports. When we first started some objected to the financial statements. They thought they were restricting them somewhat. Now they welcome them.

We get somewhat more irritation from our investigators from the standpoint of having their reports reviewed by someone on the English staff than we do in almost any other phase of our relationship. Frankly, I would be interested in hearing what Dr. Ives' reaction would be as to whether or not it would be wise for universities to send out technical reports from technical investigators done in their own delicate and delightful manner without, at times, formal appreciation as to form or sentence construction.

In conclusion, I think every member of the staff has been

willing to coöperate. Any problem which comes in we first discuss with the department head. He, in turn, makes a suggestion as to a man on the staff who is most fitted to undertake it. Naturally, we do not accept any problems unless we can find someone who is willing to undertake the investigation. Possibly that is the reason why we get the coöperation. No problem is accepted on the basis of telling a man he must do this, and he must do that. The investigation is accepted only when the man is willing to undertake the work and direct it.

H. E. Ives (Bell Telephone Laboratories): The only reaction I have to the suggestion that was made is that I think it is a very sad commentary on the preparatory teaching of English if men who are supposed to be competent to do sound, scientific work cannot express their ideas clearly when they have done the work

THE SELF-TRAINING OF A TEACHER *

By CHARLES S. SLICHTER

Dean, Graduate School, Professor of Applied Mathematics, University of Wisconsin

I

Forty-five years ago this very day—almost this very hour—I began at Wisconsin my university teaching. I cannot think of anyone less prepared in technical psychology and pedagogy for such a position. Experimental psychology was just then beginning, and the science of education was groping about like a small child. Perhaps, therefore, I should also say that I know of no one who at that date was better prepared in technical pedagogy for university instruction. I started off with four daily classes of forty freshmen each and an advanced class of two students soon dwindling to one. The universities of America have always been generous, even over-generous, in supplying an abundance of students to their green and utterly inexperienced tutors. I was so unsophisticated that I could not think of a finer job on earth than teaching mathematics to freshmen. I thought, until quite recently, that everybody was of the same opinion. It was a shock to me to learn that some think that there is a higher job. But I really did not teach freshmen. I taught attorneys, bankers, big business men, physicians, surgeons, judges, congressmen, governors, writers, editors, poets, inventors, great engineers, corporation presidents, railroad presidents, scientists, professors, deans, regents, and university presidents. That is what my freshmen are now, and of course they were the same persons then. I was teaching with such enthusiasm and was so proud of my classes that it never occurred to me that my work could be criticised. It was the self-confidence and conceit of a beginner. But President Bascom visited my classes. After each visit I was called to his office. He went over things with me, criticizing at length, but justly and with uncanny precision and directness, calling upon his imagination to say something pleasant at the end. Why did President Bascom take such trouble with an insignificant tutor? It was because he knew that I was not teaching freshmen, but the real men I have listed. That is the first lesson that the university teacher must learn. Our

* An address before the Mathematics Session of the Summer School for Engineering Teachers, University of Minnesota, September 5, 1931.

contact with students must not be at a moment nor at a point, but through the complete trend of a life, the years to come being of one substance with the present. We must be ready by our magic to roll the long scroll of a life before us to the epoch of the present or to the epoch of the future, as we will. A prophet once exclaimed: "Behold the dawn! Behold the dawn! The things as yet but half declared command the coming day."

II

The second lesson for the young teacher lies in his need to become an artist in handling human material. He should know what is going on deep in the brain of each of his students. This may not appear in the manuals of pedagogy, but nevertheless this difficult duty belongs to us. In those wonderful years following adolescence, when the pulse is steadying to a firmer beat, then youth seems to cover himself with a cloak of diffidence and timidity. The new man is imminent but hidden from view. He will hardly confess to his own father the plans, the ambitions, the dreams of service that lie deep in his conscience. To the superficial teacher he seems a trifler, but that is only the garb he assumes to hide his first aspirations to man's estate. Few young men are really triflers. Way back deep in the head of nearly every youth is the ambition and the determination to make something fine out of his life. Let the teacher discover his way to this hidden place and build his influence upon it. The teacher must train himself to be an artist in human material.

III

The third lesson for the college teacher is to learn the art of making his subject interesting. It is not the task of the teacher to teach interesting things, as the quacks proclaim. The job is to make interesting the things that must be taught. He must teach the basal sciences as they exist and it is the task of the teacher to make the things therein contained part of a living world full of the adventure and the hazards of learning. This, of course, is the reason why an instructor must be highly trained and productive in his special field and widely read in the history of science and also not ignorant of the literature of the race.

This last point deserves further elaboration, especially for the younger instructors. A sad experience in visiting a classroom is to discover many rich personalities on the student side of the rostrum but a weak or undeveloped personality on the teacher side of the rostrum. It is obvious in such a case that the teacher will find great difficulty in overcoming this potential difference. How may the teacher develop a rich personality? Unfortunately there

THE MATHEMATICS SESSION OF THE SUMMER SCHOOL FOR ENGINEERING TEACHERS, HELD AT THE UNIVERSITY OF MINNESOTA, AUGUST 24 TO SEPTEMBER 5, INCLUSIVE, 1931

The session was attended by 89 teachers, representing 60 different institutions. The staff comprised 20 lecturers.

are no psychological calisthenics that can train a weak into a rich personality. It is largely a matter of inheritance; luckily, however, it is not a matter of family but of racial inheritance. We are all mentioned in the wills of Homer and of Shakespeare and of all the great masters of letters; we do not share merely in part, but each of us inherits in full all of their rich chattels. You may be assured that great literature, great history, and great biography belong to us—even to mathematicians—and may be claimed and cultivated as our own. Hence the students have a right to find something more in the classroom than the narrow mechanics of a scientific machine. Instead of twenty times at the movies, better the guest of Homer twenty times. What has Homer to do, you will ask, with the teaching of mathematics? I use Homer, of course, merely as an example. His heavy-breasted heroes contending in the sweat of their primal passions are reacting to emotions that sway men everywhere and to motives that rule our own destiny. In the story of their strife the fibres of your being will vibrate with the ambitions and angers universal to humanity; your personality will quicken to a new appreciation of the facts of life. In other words, the ingredients necessary to compound a man can hardly be omitted from the recipe for making a teacher. You need not be afraid, therefore, to enrich your life by the cultivation of letters and by indulgence at the feast of the humanities.

If it were not for the demand of interest, perhaps we could standardize our work by questionnaires and turn the classroom over to the radio or the phonograph. Especially important is the history of your own specialty. The student needs to know the source of some of the great discoveries and the form and texture of their primitive formulation. Let him learn that one of the earliest physicists and hydraulic engineers was a barber of Alexandria of 2,000 years ago. From the money saved from shaves and haircuts he built the first valve pump and the first fire engine. If the student will inspect a village fire pump today, he will find the same curious curves to the hand brakes and to the air chamber adopted by Ctesibius twenty centuries ago. He will note in the history of technology the same useless ornamental scrolls on the handle of a hand saw that were used in Egypt 5,000 years ago. The student may forget formulas, but he will not forget the story of Archimedes running through the streets of Syracuse naked from the baths, shouting "Eureka! Eureka!" The reason is that these are human interest stories. Science is news, and at one time some of the items we teach should have been first page write-ups. Archimedes with his Eureka incident should have commanded a first page "banner spread." Human interest comes first, but a second claim for the introduction of the history of science is to

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Minnesota, August 24 to September 5, Inclusive, 1931

demonstrate that knowledge is a growing organism linked intimately with the expansion of human progress. Each age seems to have an outstanding problem to serve as a challenge to its scholars. This is the age of the Michelson-Morley experiment. The challenge of this paradox has produced more good electrodynamics and more good mathematics than thousands of successful investigations. The Michelson-Morley dilemmas of the early Greek geometors were the squaring of the circle and the tri-section of an angle. These problems brought forth more good geometry than all the solvable problems of the day. The Michelson-Morley dilemma of the seventeenth and eighteenth centuries was the problem of the complex course and irregular motions of the moon, and for more than a century it was the challenge that brought to the contest the great men of those days—Newton, Clairaut, MacClaurin, D'Alembert, Euler, Lagrange, La Place. These giants were developed in their strength by the problem of the moon. Mathematics is the story of great deeds. Its history cannot be ignored if we would face our students with enthusiasm and virility.

But mathematics has a present and a future as well as a past. Its contacts with the other sciences and its application to some of their major problems must not be unknown to the teacher. He will find ample opportunity to add interest to his instruction by limited use of such erudition. Students are interested in the power as well as in the romance of the giant we call mathematics.

IV

Fourthly, the instructor must maintain a creative contact with research in some field of learning. This observation is so trite and commonplace that I am ashamed to make it. But I mean more by it than is commonly intended in such discussions. It is the creative attitude towards all phases of life, not merely to a specialty, that I would emphasize. I learned this lesson from President Bascom years ago at college rhetoricals. The theme of his discourse was the three attitudes of the individual toward the universe: first, the cognitive attitude founded upon the desire to know; second, the aesthetic attitude, founded upon the desire to recognize and appreciate the full beauty of existence; third, the ethical attitude, founded upon the desire to achieve the highest good. I do not believe that there was anything new in that topic—very likely the theme goes back to Aristotle; but the novelty lay in what followed, for then came John Bascom's powerful exposition of the duties of life that each attitude implies. It was the duty of everybody, not the duty of specialists, to add year by year to the store of human knowledge; it was the duty of everybody, not the duty of poets and

THE CHEMICAL ENGINEERING SESSION OF THE SUMMER SCHOOL FOR ENGINNERING TEACHERS, HELD AT THE UNIVERSITY OF MICHIGAN FROM JUNE 23 TO JULY 9, INCLUSIVE, 1931

This session was attended by 69 teachers, representing 47 different institutions. The staff comprised 34 lecturers.

artists, to contribute day by day to the beauty of the world; it was the duty of everybody, not the duty of a few leaders of men, to make hour by hour the world a better place. The virility and power with which all this came forth, I, of course, cannot picture nor describe. It was the radiation from a prophet. It entered my frame and put there a tenseness that has never vanished—it changed in an instant the dynamics of my life.

I learned that day that we are not only teachers of mathematics, but philosophers of the good life. The duties press upon us to enrich and refine all contacts with the world and to hand on the spirit of it to our students.

V

The teacher cannot accomplish everything. Perhaps it is more in his power to enrich the personality of the student than it is to develop his mentality. The teacher can train the student in the facts of his subject; he can drill into him the technical skill required; he can develop in him a proper attitude toward learning; and, most of all, he can train him in proper habits of work and of self-expression. But the teacher soon comes up against a stone wall. The God-given abilities of the student, the inborn qualities necessary to success, the teacher can neither create nor augment. Education wins many victories but there are vast domains it cannot penetrate. The supreme triumph of the educational process is shown by the case of Helen Keller. All the training that a teacher can give is there illustrated by an example that everyone can understand. But the God-given abilities were present in Miss Keller at the beginning and antedated the work of the teacher—those were gifts that were not transferable and that the teacher did not create. Our freedom and the freedom of the student is harshly limited by nature. We are forced and propelled by many engines within us over which we can exert but slight control. We are propelled by our inheritance—by the powerful engine of heredity. We are propelled by our emotions—fear, vanity, and so on, and by all the range of animal passions and appetites. We are propelled by the forces of habit—"our past actions press mightily upon us for repetition." But here lies the golden opportunity of the teacher. He has marvelous power to develop the formative forces of habit before the years have made it too late. Mathematics here holds a central position and its classrooms are the best laboratories for the development of intellectual and scholarly habits. We teachers of mathematics recognize and gladly accept these responsibilities.

VI

In bringing this brief discourse to a close, I well know that I have not said what you expected me to say, nor what you wished me to say. You desired, I am aware, a discussion of direct concrete items of technique. You wished to know of standardized procedures, supported by questionnaires and comparative tests. I have deliberately and knowingly seen fit to disappoint you. I have done this because I feel the need at the present moment of shifting the emphasis to the temper and the spirit of our duties, rather than to their technique. Teaching is more than an art to be practiced—it is a life to be lived. At the present moment it is important to stress the activities that are attractive to the gifted teacher. There is today urgent need to insist upon a teaching staff of virility and catholic personal qualities. We must have help at this point from the faculties and from all the university authorities and from the public. The greatest obstacle to the attraction of gifted men and women to the teaching profession, and the greatest discouragement to their continued enthusiasm and success, is the wide open admission to the freshman class of incompetents and the mentally dull. Certain inborn abilities must be brought to college by the student himself—the university can neither create nor augment them. Some selection, some rejection, much encouragement to the gifted student (whether rich or poor) is a St. Peter's job at the college gate. Stanford University, California Institute of Technology, and a few others have shown the way. Unless we can restrict college admissions to those who possess a minimum of inborn abilities, no amount of pedagogy and no amount of instructional skill and no amount of enthusiasm and self-training can prevail. A beginning in the selective admission of students is being made—it should be hastened and the support of the public should be forthcoming. Other things seem favorable; the competition for positions is becoming keener, the salaries are slowly moving to a higher level, and the qualifications for the Doctor's degree tend to become more exacting. It has seemed well, therefore, for me to emphasize the higher qualities the teacher should develop by careful self-training and whole hearted devotion to his students. He can be assured that there is no vocation where there are so many good things to do and that leads so readily to contentment and the sense of victory. Although by temperament and other qualities I was ill adapted to the life of a teacher, I wish to testify after all these years that it is indeed the good life we attain—I am sustained and confirmed by its many rich rewards.

DISCUSSION OF EMPLOYMENT OF 1931 GRADUATES

H. S. Rogers (Oregon State College): I don't know whether Dean Bishop was throwing any insinuations at the Western colleges in our efforts to export our students to the East or in the eastward migration of trained men each year. I don't know whether I should interpret him as indicating that we did not develop the field in which they could be absorbed in our own territories or not, but the facts are these: that we have at all times placed in the West about as many men as the field would absorb, and that field is about the same this year as it has been at other times.

We have placed, however, a very much smaller proportion of our men than heretofore, the proportion in my own school being about 40 per cent. Last year, out of 102 graduates we placed 40 east of the Mississippi River and this year we placed two. The difference in the placement of this year for our students is that we have no eastern market, and we have approximately the same kind of a western market as we have had in the past.

A. D. Moore (University of Michigan): In a normal year our graduates are placed before graduation. We usually manage to place them in an engineering job, or at least a job college graduates want to have. Whether it is engineering or not does not make so much difference. In an abnormal year, such as we have this year, we are likely to think of the boy who is going back to the farm where he has three meals a day, and would like to think of him as being placed.

I should like to inquire, in connection with the report, what placement means. It looks to me as though 38 per cent was entirely too optimistic.

Paul Cloke (University of Maine): That is exactly what I think, Mr. Moore. When I got this questionnaire, I answered it from the standpoint of the men placed in engineering work now, not next February or next June, and I did not include the men taking graduate work. We placed 18 men out of 100 whom we graduated in engineering work, but we placed a much larger number of men in something or other. I reported 18 per cent.

D. C. Jackson, Jr. (University of Kansas): We had the same problem in Kansas when the questionnaire came in. Dean Shaad put it up to his departments to report the status of their senior classes. I had rather a sizable proportion of the senior class who were taking graduate work.

Personally, I feel that whether it is a good year or a bad year,

a man who decides to go on with graduate work is just as definitely placed as a man who gets a job. In fact, I rather feel he is a little better placed, and I so reported it, but separated it from the men who had jobs. Some of those students who are going on with graduate work have paying jobs and as such they should be reported.

I would like to see this questionnaire include all men, with or without paying jobs, who are doing graduate work next year. Also, I do not feel it is necessary to include only those men who have a job immediately after graduation. If they have an offer to have them report next February, they are just as definitely placed as though they were to report on June 15. I would like to know what the results of this questionnaire mean.

Dean Cloke: I can not agree with that point of view at all. The man ranking highest in our senior class had to stay to take graduate work because he received word from the General Electric Company he would not be taken until possibly next June. He is a poor boy coming from a farm and he has to live between now and next June on something or other, and that is just the point to the matter. We ought to have a very definite specification of what we mean by placing a man.

A. D. Moore (University of Michigan): I don't wish to be a pessimist, but I think we could easily be misleading in some of these matters.

I can give a very good looking report for electrical graduates from the University of Michigan by saying one-third of our June graduates are placed, and that does not include coming back for a graduate year. It does include what I feel to be definite employment, even though that employment will be deferred until March, let us say.

One-third of the June graduates do not tell the story in our school, at least. We graduate a fair number of men in February and again a fair number of men at the end of the summer school. The honest way to count is to count the number of men graduated in the year 1931, which will be about 64 men instead of 45 in June. Therefore, we are placing about one-fourth of our 1931 graduates, 25 per cent. I cannot believe the average for the country placements in actual engineering jobs of the usual kind will average higher than 25 per cent.

A. M. Dudley (Westinghouse Electric & Manufacturing Company): I suppose industry should not sit here and say nothing at all even if it be that it cannot absorb all the graduates it ought to this year, or creates that impression.

As regards being the prophet or the son of a prophet, I don't know that any of us want to commit ourselves. Mr. Babson committed himself very definitely last week to the effect that we have

seen the worst of this. We all hope he is right. At the same time, I believe two things will happen to us. I think we will have too many graduates again next June, and I think four years from now we will have too few because a lot of the freshmen got scared out. Those two things are pretty reasonably sure of happening.

I might tell you a little story that came up. Part of this pessimism of Mr. Moore's was absorbed in the state college in May when we were down to Dean Sackett's usual conference between the colleges and industry. We are trying to make a résumé of this same kind of data, and from the available sources, which were not very exact, it looked like about 20 per cent. That was fairly early in May.

There was one very amusing story that came out that might help all of us here, including our brethren from east of the Mississippi River who perhaps have not exploited all the possible means of placing graduates, to this effect: In a year like this a firm which was in the fur business in New York state needed some men, and since there were some very active engineering candidates, they decided to take two electrical engineers, with such surprising success that they now insist on having electrical engineers in the fur business.

Chairman Harding: There is a chance for experiment in rubbing the cat's back after all.

M. B. Robinson (Cincinnati Milling Machine Company): I have been much interested in these figures. It seems to me that the purpose of sending out this questionnaire was to measure the demand this year for your product.

When a graduate goes to a farm he is still potentially available for an engineering job. He is going to apply for an opening when the right kind of an opening presents itself. Therefore, I do not think that man should be counted as being placed.

It seems to me Dean Cloke said he had only counted the graduates in engineering positions. It seems to me he is right in that. Unless we follow that interpretation of the questionnaire these figures do not measure what the demand has been for our product. I think in years to come we will be very glad to have some sort of record of the demand for the engineering graduates this year. We all hope and believe that this depression is not going to last, but judging from past history it is a recurrent thing.

I really think this questionnaire ought to be recirculated as of July 1, August 1, or September 1, whatever you decide, and lay down a uniform interpretation of what is meant and get those figures on record. I should just like to suggest that.

E. B. Roberts (Westinghouse Electric & Manufacturing Company): I am not very much concerned about the particular figures

in the questionnaire or just exactly how they are to be interpreted. I am perfectly satisfied in my own mind that the true figure is somewhere around 20 per cent.

I think the bigger question is: What are we going to do about that matter, and what are the schools going to do this fall when they get so many men returning, unlooked for, asking for further work of some kind? I know most of those boys are going to ask for graduate work because they do not know what else to ask for.

I have a feeling in my own mind that if many of those men can be stimulated to take further undergraduate courses in other engineering or allied fields they will be distinctly better off than the great majority of them will be if taken into graduate classes, for we all recognize that all the men that come from undergraduate work should not do graduate work.

I offer the suggestions that educators to whom this question comes consider, when the time arrives, influencing those men who graduated in one school to take further work in another school; the electrical engineer take mechanical engineering, and the mechanical engineer perhaps take work in the electrical field, and possibly both of them in the field of business, administration or industrial engineering, economics, or what not.

Chairman Harding: I feel that is a very pertinent suggestion.

A. H. Fuller (Iowa State College): If this questionnaire should be recirculated as has been suggested, another phase should be included, those who are permanently employed and those temporarily employed. Many of our men this summer have taken temporary employment of a worth-while nature where they are getting engineering experience. One is in Pittsburgh and one is in West Virginia and they go out as laborers at fifty cents an hour. They are where they are getting experience, and they will have permanent positions with the company when the time comes. Going through our list, we have rather a large proportion who are employed that way, not permanently employed, but in positions which give them experience.

I think that is a good factor, if we are going to follow this matter up. Those temporary positions will lead to worth-while permanent ones.

Chairman Harding: Do I hear any motion regarding the questionnaire? It is appropriate at this time.

Dean Cloke: I make a motion that this be considered by the administrators of the Society and resubmitted considering the discussion and suggestions that have been made. Motion carried.

REPORT OF THE DIVISION OF MECHANICS OF S. P. E. E.

1930–1931

On account of interest in the matter expressed at the Conference of the Division at Montreal in 1930, it was the plan of the Executive Committee of the Division to hold a two-day Conference on the Teaching of Mechanics immediately preceding the 39th Annual Meeting of S. P. E. E. at Purdue. The sessions were to be modeled very much on the plan of those of the four-day conference held at Columbus in 1929.

Before plans had proceeded very far, however, a request was received from the Applied Mechanics Division of the A. S. M. E. that they be permitted to hold their Annual Meeting in connection with the Purdue Meeting of S. P. E. E. The program was to consist chiefly of technical papers on the application of the principles of mechanics to the solution of new problems in industry. By holding the two meetings together, they hoped to obtain the interest and the attendance of a larger number of the teachers of Mechanics than they could hope for at a separate meeting or at one in connection with the regular A. S. M. E. meeting. It was felt by our Executive Committee that this plan was eminently desirable and that our Division could well afford to postpone our proposed Conference on the Teaching of Mechanics for a year or two. We so assured the Committee of the Applied Mechanics Division of the A. S. M. E., and gave them every aid in arranging for the meeting. Four splendid technical sessions were held on Monday and Tuesday, June 15 and 16, at which seventeen papers were presented. A mere statement of the program must suffice here, and will be found at the end of this report. For the contents of the papers presented, see the publication of the A. S. M. E.

On Monday evening, a dinner was arranged at which 170 were present. It was impossible to keep technical matters out, even on such an occasion, so following the dinner Mr. C. R. Soderberg of the Westinghouse Electric and Manufacturing Company read a paper on "The Significance of Applied Mechanics for Engineers."

On Tuesday evening, Dr. O. G. Tietjens and Mr. G. B. Karelitz showed five reels of Research Films on the flow of air and water past moving models of various shapes, including a reel of Japanese films, some of which were taken at the rate of 40,000 exposures per second.

In connection with the meeting, a number of instruments and

machines were exhibited, illustrating features of some of the papers presented. Exhibits were shown by the General Electric Company, the Westinghouse Electric & Manufacturing Company, the Vibration Specialty Company, and by Professors J. A. Van Der Broek, M. M. Frocht and P. W. Ott.

The Conference of the Division of Mechanics of S. P. E. E. was limited to a two-hour session on Wednesday morning, June 17. Under the title, "Pseudo-Mechanics," Professor E. R. Maurer, of the University of Wisconsin, called attention to some faulty mechanics used in a standard steel handbook. After a number of interesting comments and much discussion, the Division adopted a resolution endorsing the efforts of the Executive Committee to obtain the elimination of the faulty material.

The chief paper of the session was presented by Professor G. P. Boomsliter, West Virginia University, on the subject, "The Relationship between Class Work in Strength of Materials and the Materials Testing Laboratory." This paper will be found on page ( ) of this issue. General discussion followed the reading of the paper, during which several subjects for future study by the Division were suggested.

Professor W. B. Wendt, University of Louisville, Louisville, Kentucky, spoke on the difficulty he had experienced in obtaining various kinds of materials to be tested in the laboratory in the small quantities they required. Salesmen were glad to quote prices on car load lots, but an order for a half dozen bars was likely to be pigeonholed. As a remedy, Professor Wendt suggested that a committee of the Division be formed for the purpose of collecting information available as to sources from which such material can be obtained. The suggestion was accepted and such a committee will be appointed.

Respectfully submitted,

A. P. POORMAN,
Chairman Executive Committee,
Division of Mechanics.

PROGRAM OF APPLIED MECHANICS NATIONAL MEETING, PURDUE UNIVERSITY, JUNE 15–16, 1931

MONDAY, JUNE 15

9:00 A.M. Stress Analysis Session.

Chairman: C. R. SODERBERG, Development Div. Engineer, Power Engrg. Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

"Spiral Springs," by J. A. VAN DER BROEK, Prof. University of Michigan, Ann Arbor, Mich.

"Recent Advances in Photo-Elasticity and An Investigation of the Stress Distribution in Square Blocks Subjected to Diagonal Compression," by MAX M. FROCHT, Asst. Prof., Carnegie Institute of Technology, Pittsburgh, Pa.

"The Flexibility of Corrugated Pipes Under Longitudinal Forces and Bending," by L. H. DONNELL, Prof., Research Fellow, Guggenheim Aeronautical Inst., California Inst. of Tech., Pasadena, Cal.

"The Strength of Thin Plates in Compression," by DR. T. VON KARMAN, Director, Guggenheim Aeronautical Lab., ERNEST E. SECHLER, Instructor, California Inst. of Tech., L. H. DONNELL, Prof., Research Fellow, Guggenheim Aeronautical Inst., California Inst. of Tech., Pasadena, Cal.

1:30 P.M. Stress Analysis and Plasticity Session

Chairman: E. L. ERIKSEN, Prof., University of Michigan.

"Thermal Stresses in Thin-Walled Cylinders," by CLARENCE H. KENT, Prof., Head of Dept. of M. E., University of Arkansas.

"Strength of Materials Subjected to Shear at High Temperatures." by FRANKLIN L. EVERETT, Research Engr., Dept. of Engrg. Research, University of Michigan, Ann Arbor, Mich.

"Flow of Steels at Elevated Temperatures," by F. P. COFFIN and T. H. SWISHER, Research Laboratory, General Electric Co., Schenectady, New York.

"Concerning the Yield Point of Mild Steel," by C. W. MACGREGER, Research Engr., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

"The Center of Torsion for Angle and Channel Selections," by W. L. SCHWALBE, Asso. in Theoretical & Applied Mechanics, University of Illinois, Urbana, Ill.

TUESDAY, JUNE 16

9:00 A.M. Vibration Session

Chairman: DEAN R. G. DUKES, Purdue University, Lafayette, Ind.

"A New Type of Dynamic Balancing Machine," by ERNEST L. THEARLE, Research Engr., General Electric Co., Schenectady, N. Y.

"Noise Prevention Through Elastic Suspension," by E. H. HULL, Research Engr., General Electric Co., Schenectady, N. Y.

"The Sub-Critical Speeds of the Rotating Shaft," by C. RICHARD SODERBERG, Development Div. Engr., Power Engrg. Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

"Forced Vibration With Combined Coulomb and Viscous Friction," by J. P. DEN HARTOG, Engr., Research Dept., Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa. (by title.)

1:30 P.M. Hydrodynamics Session

Chairman: M. L. ENGER, Prof. Mechanics & Hydraulics, Univ. of Ill., Champaign, Ill.

"Propeller Type Fan," by DR. O. G. TIETJENS, Westinghouse Elec. & Mfg. Co., E. Pittsburgh, Pa.

"The Hydraulic Jump and Related Phenomena," by BORIS A. BAKHMETEFF, Consulting Engr., New York, N. Y.

"The Boundary Layer and Skin Friction for a Figure of Revolution," by CLARK B. MILLIKAN, Asst. Prof., Aeronautics, Daniel Guggenheim Graduate School of Aeronautics, California Inst. of Tech.

"Jets From Manifold Tubes," by JAKOB KUNZ, Prof. of Physics, University of Illinois, Urbana, Ill.

Exhibit of Research Apparatus

During the meeting there were on exhibit in the Electrical Engineering Building, the latest in special research apparatus, among which were: balancing-machine models illustrating shaft whipping, vibration-recording apparatus, sound-deadening device, photo elastic equipment, apparatus for obtaining space-time curves, ap paratus showing buckling of bars, small fatigue machines, tensile testing machine, exhibition of fractures, gear damping, etc.

The exhibits were set up in the laboratories adjoining the ses sion room and connected up so that they could be demonstrated during the meeting.

THE RELATIONSHIP BETWEEN CLASS WORK IN STRENGTH OF MATERIALS AND THE MATERIALS TESTING LABORATORY

By G. P. BOOMSLITER,

Prof. of Mechanics, West Virginia University

A college is a reflection of its faculty. Our most eastern school prepares many men for irrigation work in the far west. Some of our best mining schools are considerably far removed from the mines. The train caller's college yell of the Kansas prairies echoes at assemblies of young electrical engineers at Schenectady. Peculiar arrangements of courses, emphasis on certain features of the curriculum and laboratory arrangements and facilities can often be traced to certain strong men, who are or have been on the various faculties.

Nowhere, perhaps, is this fact more emphasized than in the administration of the various courses in mechanics. We find such courses given in the departments of physics, of mathematics, of mechanics and of civil and mechanical engineering. A study by Dean C. R. Jones, of West Virginia University, which included about 100 schools, shows 4 schools giving mechanics in the physics department; 9 in the mathematics department; 20 and 22 in the departments of mechanical and civil engineering, respectively, while 36 had separate departments of mechanics. It would thus seem that the plurality, at least, feels that all departments of the College of Engineering are best served when mechanics is in a separate department, emphasizing the peculiar needs of no one department, but endeavoring to serve all, and also is under the control of the College of Engineering, with engineering graduates as teachers.

At the summer session for teachers of mechanics, held at Madison in 1927, the committee on organization and administration of courses in analytical mechanics recommended disposition of these and related courses as follows: *

First. That the department of physics or of mathematics and engineering handle these subjects with their own in the small engineering school giving but one degree.

Second. In the larger engineering schools giving separate

* S. P. E. E. Journal, Feb., 1928, p. 616.

degrees in engineering, a non-curricular department of applied mechanics should handle the basic courses in analytic mechanics, strength of materials and testing laboratory. They also recommend one hour of recitation in materials of construction and one credit hour of laboratory in materials testing to be given simultaneously with mechanics of materials.

Even more variation in the control of the course in materials testing and its connection with other related courses, was shown in Dean Jones' study. The following table was compiled from this study. It was found difficult in some cases clearly to place this course from the catalog announcements. In some instances, this course was given only to certain groups of students, those in civil or mechanical engineering, for instance. In a few large schools, separate courses were given to civil and mechanical engineering students, sometimes in separate departments.

TABLE I

MATERIALS TESTING IN AMERICAN COLLEGES OF ENGINEERING

Course with Which Materials Testing Is Combined	Department Giving Materials Testing					
	Mechanics	C.E.	M.E.	Math. & Mechanics	Exp. Eng'g.	Totals
Mechanics of Materials	11	10	5	1		27
Materials of Engineering	4	9	2	1		16
Separate	8	21	11	2	1	43
General Laboratory Course	0	2	8		1	11
Totals	23	42	26	4	2	97

This table shows that the course in materials testing is given in the departments of mechanics, civil or mechanical engineering, mathematics and mechanics, and experimental engineering. It is given either as a separate course or as a part of mechanics of materials, materials of engineering or of a general laboratory course. In 30 cases this course is given simultaneously with mechanics of materials, but in many instances it was given separately at a different time from the mechanics.

In view of the wide divergence of practice, it seems wise to discuss the best disposition of the course relative to those whom it serves. Whom should it serve? It is generally agreed that all groups of students should have courses in applied mechanics and mechanics of materials. Materials testing as an adjunct of the classroom course is an excellent aid in emphasizing the funda-

mental concepts of this course. In addition, civil engineers engaged in construction work should have an intimate knowledge of the properties of materials and the tests for such properties. Mechanical and electrical engineers are concerned particularly with the methods of modifying the properties of the metals to serve their many purposes, while chemical engineers are likely to be concerned with the early development of new combinations of materials. A classroom course in materials of engineering can be well supplemented by a course in the testing laboratory.

In many cases the department for giving the course in materials testing has been selected on the grounds of economy and expediency. This is certainly true in the case of the smaller schools, with small enrollment and faculty and limited equipment. It would generally be true, for example, in those instances in which mechanics is given by the departments of mathematics or physics in which the instructors usually have had no engineering training. In many instances, also, this laboratory work is given only to civil engineering or mechanical engineering students and would thus naturally be given by these departments. It is interesting to note that the department of mechanics gives this course in 23 instances; mechanical engineering in 26 instances, and civil engineering in a total of 42 schools.

Perhaps partial explanation of this disposition of materials testing may lie in the varying emphasis on the objectives of the course at the various schools.

These objectives may be stated as follows:

1. To give the student first hand knowledge of the behaviour of materials.
2. To acquaint him with the various types of testing apparatus and their operation.
3. Drill in the standard tests for materials.
4. To enable him to make intelligent selections of materials for various purposes.
5. To show the effect of alloys and variations in quality on the various properties of materials.
6. Drill in curve plotting and the interpretation of curves.
7. Drill in report writing.

At the summer session previously referred to, Professor H. F. Moore * gave 4 objectives for a course in materials testing, as follows:

1. For a study of the laws of mechanics of materials.
2. For the study of the basic properties of the materials of construction.

* Ibid., p. 576.

3. For training in the technique of handling testing apparatus, and

4. For secondary purposes including

(*a*) The furnishing of contact between college and industry.

(*b*) Development in the student of an appreciation of the proper degree of accuracy and sensitivity in experimental work.

(*c*) The study of mechanical substitutes for mathematical analysis.

At this meeting it was stated that some laboratories were used entirely for the second purpose, while others combined (1) and (2).

The table shown indicates that 16 schools give materials testing as a part of mechanics of materials. Of the 43 which give materials testing as a separate course, 30 give the course at the same time that mechanics of materials is given. In other words registration in the laboratory course is a prerequisite to registration in the classroom course. In many of these cases the first objective stated previously, *i.e.*, to give the student first hand knowledge of the behavior of materials, is the principal one. The instructors in this instance feel that the most effective way to learn the effect of beam action, of elasticity or twisting or of memorizing the properties of materials, such as the proportional limit, yield point and ultimate strength, to be used in the classroom in design and investigation, is to have the student experience the action himself. Only in that way can he get the proper concepts of the action of materials. His judgment will be ripened and numerical values will remain in his memory much longer than if such laboratory work is given in some other form. In writing up his experiments he will be required to answer questions which will emphasize the points which they are designed to bring out. Many of those present have doubtless had laboratory squads who tried to calculate the load which would be carried safely by a beam, through the use of the equation $S = P/A$. Until it was encountered in the laboratory a beam was a sketch, not an actual part of a structure.

Such instructors do not lose sight of the importance of the fact that the tests performed are standard tests, nor do they neglect the use of experiments showing the effect of alloys or other variants on the properties of materials. Concretes are made and tested with varying water-cement ratios, and at varying ages; the strength of timber is found with different percentages of moisture, etc., but the principal objective is to use the course as a valuable aid to the study of the theory of materials.

On the other hand, when the course is given as an adjunct to

materials of engineering, the fourth objective, *i.e.*, to enable the student to make intelligent selection of materials for various engineering purposes, becomes of prime importance. The effect of carbon, of heat treating and cold working on the properties of steel are studied. Standard tests of various kinds on many materials are determined and comparisons are made of tests with requirements as expressed in the A. S. T. M. standards to determine whether or not the material is acceptable. Thus the emphasis is shifted by this group with a possible lessening of its value as an aid to classroom instruction.

As a general rule, the value of the materials testing is much reduced when made part of a general laboratory course, especially when the instructor is not in close contact with the instructors in the closely allied classroom courses. It also seems that much of value in such a course is lost if it is given in a different semester than is the classroom course. It may be argued that in this manner the concepts of mechanics will be carried through a longer period so that a greater residuum will be retained of the knowledge which has been gained. As a matter of fact, unless carefully administered by trained men, the work tends to degenerate into a routine of testing and report writing that has little of value for the student.

Many schools have been able, by intelligent planning and with a competent corps of instructors, to combine all of the objectives above listed in the conduct of materials testing courses in an effective manner. In the majority of such cases it will probably be found that the courses are under a department of mechanics. When given under some other department, diversity of interest on the part of the teaching staff, or emphasis upon those factors which apply peculiarly to the given department, are likely to affect its value for students from other departments.

Combined vs. Separate Courses in Materials

The previous table showed that 43 schools give materials testing as a separate course, while the same number combine it either with mechanics of materials or materials of engineering. Each plan has its disadvantages.

When given as part of the classroom course, the student will be certain to take the course at the most favorable time. Should the student fail in the classroom course and pass the laboratory work, he could be excused from the laboratory work on repeating, but if the failure is in the laboratory, the case is awkward, as a recorded failure of 5 hours is a serious matter and does not indicate the actual facts. When the testing course is a separate entity, this difficulty is obviated but irregularity of schedule is likely to tempt

the registering officer either to omit the laboratory course when it should be assigned, or to enroll the student in such work before he is prepared for it. The solution would seem to be to give the courses as separate courses, but make enrollment in one a prerequisite to enrollment in the other. This could be assured by a check of the names in the two courses immediately after the completion of registration.

Credit to be Given for the Course

In the investigation referred to it was found that 35 institutions gave one hour of credit for the course in materials testing. One gave 1½ hours credit; 14 gave 2 hours credit; 2 gave 3 hours credit and one 4 hours. A laboratory course which takes 2 or 3 hours of work in the laboratory and anywhere from 2 to 6 hours for preparing the report, takes more of the student's time than he can fairly allot to a course of so little credit. Several such courses in a student's schedule coupled with enough other hours to give him an 18 hour schedule will impose too great a burden upon him and he often groans and sometimes breaks under the load.

On the other hand, engineering courses in general are heavily loaded—in our own school we ask for 22 more hours than are required by the College of Arts and Sciences so that it may be well nigh impossible to make the course count for more than one hour.

One solution that has been tried with considerable success is to reduce the working time in the laboratory to about 1½ hours, and then allow the various squads to write up a single squad report before the end of the period. If this report is not acceptable it must of course, be corrected and returned later, necessitating work out of period. In general, however, the students soon learn to work rapidly and carefully so that such extra work is soon reduced to a minimum. In order to provide that the drones shall not get credit for work done by their more industrious brethren, an examination can be given which soon becomes a tradition and teaches them that all must be fully familiar with the work done each week.

Although the student becomes familiar with the operation of the testing machines in his laboratory and with the use of supplementary apparatus, machines change and no one laboratory will acquaint him with more than a few of those with which he will come in contact.

Our foremost teachers in mechanics feel that the writing of satisfactory reports is one of the most important features of a course in materials testing. Professor Moore feels that a report should take as much time as the test itself and that a generous amount

of time should be allotted for this purpose. Professor Upton of Cornell University, states that Cornell students consume from 9 to 10 hours on their reports. The previous comment concerning credit for the course becomes pertinent under such conditions.

The material in this table shows that although in many institutions the question as to the disposition of courses in materials testing has been settled, there is a considerable difference in point of view throughout the country and many institutions are, or may come into a state of flux with respect to their curricula, and the subject will become a live one and it will become important to make a wise decision in the matter. This is the sole object in the writing of this paper.

Discussion

Professor W. E. Brooke stated that teachers of mechanics should be engineers with good training in mathematics, instead of mathematicians with training in engineering.

Professor M. M. Frocht discussed the necessity of correlating class work with testing laboratory work because of the aid of seeing to memory. He said that we should guard against over-emphasizing the need of mathematics in applied mechanics. He said that he felt that mechanics and the laboratory work should go first and that mathematics should come later, only as far as practical necessity requires.

Professor R. H. Danforth stated that in organizing and giving undergraduate work in mechanics it should be kept in mind that applied mechanics will grow in use in the next few years. He stated further that the growth in mechanics will be in other branches than statics and that, with the tendency for mechanics to become more and more mathematical, will come a requirement for special instructors in this subject.

Professor A. E. Norton expressed the feeling that laboratory work should be an intensive study of the test of one material with a thorough understanding of the methods and purposes involved, rather than the superficial testing of many materials.

Professor M. F. Sayre expressed the belief that future developments will bring about or force coördination of class work and laboratory work. In the past, the requirements of the mechanics laboratory have been for structural testing only. He anticipates that there will be new requirements for laboratory work in mechanics in many other fields. The recent developments in investigation of plasticity and photo-elasticity were given as examples of the trend of applied mechanics laboratory work. He said that he felt that the laboratory work and the class work should be given in the same department.

CONFERENCE ON MACHINE DESIGN AT THE ANNUAL MEETING OF THE S. P. E. E.

Professor James A. Hall of Brown University presented a paper on "College Training for Engineering Student in Machine Design," and Mr. Edwin H. Brown, Engineering, A. O. Smith Corporation, Milwaukee, presented a paper on "The Selection of Design Engineers." Professor Frank L. Eidmann presided.

There was an attendance of 86 at the conference and a lively and stimulating discussion followed both papers. To allow for additional discussion a special meeting was arranged, which was attended by 33.

It was the consensus of opinion of the machine design group that the scheduling of conferences was very satisfactory and that the arrangement for special meetings furnishes an ideal way of getting together those members interested in more discussion than could be provided for in the pre-arranged program.

FRANK L. EIDMANN,
Chairman.

The T-SQUARE PAGE

DEVOTED TO THE INTERESTS OF THE DIVISION OF ENGINEERING DRAWING

FREDERIC G. HIGBEE, EDITOR

Progress in Educational Measurements.—Professor C. V. Mann reports that the 1930 graduating class of his institution was given placement tests when it entered as freshmen, and that 37 of the original group of 160 received degrees. His test in Engineering Drawing made the best prediction of any single test, and better than the prediction of all tests pooled.

Only two of the 37 who graduated came from below the middle rank of the class as fixed by first year scholarship. No placement test was more than 70 per cent effective in selecting the individuals who constituted this upper half of the class as established by scholarship. The Iowa Chemistry training test was best for picking the upper 5 per cent of this group, the Iowa Mathematics training test was thereafter best for picking the remainder of this upper half of the scholarship group, and the drawing test was 69 per cent effective in sorting out the poor students.

Professor Mann concludes: "We have gone far enough with Placement Tests to know fairly well what they measure, and how reliable they are in predicting four year success. My guess is that a high general intelligence is the main factor in success in engineering study. . . . There may be a few special traits that are worth measuring, and if so, the power to visualize is one of them."

Professor Mann is now making up a test to measure this trait and is working on a program of research looking toward the measurement of the increment which the study of descriptive geometry contributes to this power.

Books for teachers of Engineering Drawing.—Contributed by Newlin D. Morgan, Associate Professor of Architectural Engineering, University of Illinois:

"Bridges; a Study in Their Art, Science, and Evolution"—Charles S. Whitney. W. E. Rudge, New York, 1929, $20.00. Part one deals with bridges from Roman to modern times; part two emphasizes materials of construction, treating bridges of wood, stone, concrete, and steel. Well illustrated.

"Bridge Architecture"—W. J. Watson, New York, Helburn, 1927. Sub-title indicates the scope of the book: "containing two hundred illustrations of the notable bridges of the world, ancient and modern, with descriptive, historical, and legendary test"; good illustrations, many of which are full page.

SOME ADVANTAGES OF COÖPERATIVE ENGINEERING EDUCATION

D. C. JACKSON, JR.,

University of Kansas

The coöperative plan in engineering education at the end of its twenty-fifth year in this country is in a healthy condition. The graduates of coöperative courses are well-considered by their employers and in general are satisfactory and successful in their work. The reasons for this are rather evident. The coöperative work intensifies the interest of the students in the studies in the classroom and laboratory due to their finding practical application of the knowledge shortly after its acquisition. The embryonic engineers earlier come into contact intimately with experienced and mature men. They learn much from these men, both the leading engineers in the company and the skilled laborers. Before graduation, the students meet the competition of our mechanistic life and learn to cope with it successfully and without discouragement. The alternate periods of study and practical work provide a mental refreshment and stimulant and show to the students very definitely the difference between the trained and the untrained mind, which in turn stimulates interest in purely analytical work. The engineering curriculum develops the ability to make accurate analyses, to arrive at definite conclusions, and to take immediate action, but in most engineering schools this ability must be limited largely to materials. In schools using the coöperative method, the students have a broader field of training and at regular and frequent intervals deal with men as well as materials. This brings to them at an early stage the opportunity to study some of the problems of the executive, and to develop and exercise in an elementary way what supervisory ability they may possess. Thus the coöperative graduates are useful and successful in the industries, both immediately after graduation and as they gain greater experience.

It is obvious that the engineers who studied under the coöperative plan have had a contact with workmen which gives an insight into the worker's viewpoint that could not be had by men going directly from college to "white-collar jobs." This contact also forces them to develop tact to a certain extent and thus enables them to gain more easily the confidence of their associates, both under and over them. But the value of the engineers who studied under the coöperative plan is not limited, as it might seem, to manufacturing establishments, operating companies, or construction firms, nor is it confined to certain of the functional divisions of engineering commonly associated with these types of organizations, such as design, production, operation, sales, and construction.

The benefit of coöperative training in engineering research and education may not be so apparent. However, the qualities gained during the coöperative work are quite as useful in these fields. Tact and the understanding of human nature is important. Analytical ability is unquestionably a necessity and executive ability is useful as well. The competitive aspect, although not so noticeable, exists also in these fields, and the faculty of withstanding competition is therefore valuable. As already pointed out, all these qualities are developed by coöperative training. The contact of coöperative graduates with the practical side of engineering makes them especially useful in their early years in research or teaching and shows them the necessity of maintaining this contact, which in turn enhances their value to engineering schools and research organizations. Thus coöperative training develops qualities which are of advantage regardless of the type of work in which the coöperative graduates may engage.

NEW MEMBERS

BOELTER, LLEWELLYN M. K., Associate Professor of Experimental Engineering, University of California, Berkeley, Calif. James R. Lorah, H. B. Langille.

BRANDT, CARL D., Head, Textile Engineering Department, Texas Technological College, Lubbock, Texas. C. L. Svensen, W. E. Street.

CHERRY, CARLETON E., Instructor in Engineering Mathematics and Mechanics, Marin Union Junior College, Kentfield, Calif. H. B. Langille, F. H. Cherry.

CLELAND, RALPH R., Instructor in Sanitary Engineering, Pennsylvania State College, State College, Pa. E. D. Walker, R. E. Minshall.

CLEMENTS, GUY R., Professor, United States Naval Academy, Annapolis, Md. Wm. J. Berry, H. P. Hammond.

ELGIN, JOSEPH C., Assistant Professor of Chemical Engineering, Princeton University, Princeton, N. J. Arthur M. Greene, H. P. Hammond.

HOOVER, P. L., Associate Professor of Electrical Engineering, Rutgers University, New Brunswick, N. J. P. H. Daggett, H. D. Hatfield.

HORTON, PAUL M., Professor of Chemical Engineering, Louisiana State University, Baton Rouge, La. H. P. Hammond, A. H. White.

HOWE, EVERETT D., Assistant Professor of Mechanical Engineering, University of California, Berkeley, Calif. H. B. Langille, B. F. Raber.

JENKINS, HOWARD M., Assistant Professor of Electrical Engineering, Swarthmore College, Swarthmore, Pa. S. B. Lilly, C. G. Thatcher.

LAWALL, CHAS. E., Director, School of Mines, and Extension of Industrial Sciences, West Virginia University, Morgantown, W. Va. G. P. Boomsliter, W. W. Hodge.

LEHMANN, CHARLES H., Instructor in Mathematics, Cooper Union, New York City. E. R. Hedrick, F. L. Bishop.

MADIGAN, JOHN A., Professor of Mathematics and Engineering, College of St. Thomas, St. Paul, Minn. O. M. Leland, H. P. Hammond.

NELSON, WILLIAM P., Director of College Relations, New England T. & T. Co., 261 Franklin St., Boston, Mass. O. W. Eschbach, H. S. Sheppard.

NEWTON, ROGER H., Instructor in Chemical Engineering, Yale University, New Haven, Conn. J. R. Lorah, H. P. Hammond.

PADDOCK, RUSSELL G., Professor of Mechanical Engineering, University of Arkansas, Fayetteville, Ark. W. A. Knapp, A. A. Potter.

PHILLIPS, JOHN B., Lecturer in Chemical Engineering, McGill University, Montreal, Canada. W. M. Cobleigh, H. P. Hammond.

RUGGLES, SYDNEY L., Resident Engineer, Vermont State Highway Department, Bellows Falls, Vt. F. L. Bishop, Nell McKenry.

SADOWSKY, MICHAEL A., Assistant Professor of Mathematics and Mechanics, University of Minnesota, Minneapolis, Minn. O. M. Leland, H. P. Hammond.

SHELDON, ERNEST W., Professor of Mathematics, University of Alberta, Edmonton, Canada. E. V. Huntington, D. C. Sheldon.

SPENCER, HENRY C., Instructor in Engineering Drawing, A. & M. College of Texas, College Station, Texas. A. Mitchell, F. C. Bolton.

STOUT, CLAUDE E., Head, Department of Mathematics, General Motors Institute, Flint, Mich. E. R. Hedrick, F. L. Bishop.

WILBRANDT, FRANK C., Professor of Chemical Engineering, Iowa State College, Ames, Iowa. H. C. Peffer, H. P. Hammond.

WEBBER, W. PAUL, Professor of Mathematics, Louisiana State University, Baton Rouge, La. H. P. Hammond, Louis O'Shaughnessy.

NECROLOGY

GEORGE FILLMORE SWAIN

George Fillmore Swain was born in San Francisco, California, on March 2, 1857, and died at his summer home on Squam Lake, New Hampshire, on July 1, 1931. He was the son of Robert Bunker and Clara Anne (Fillmore) Swain.

In 1873 he entered the Massachusetts Institute of Technology to prepare himself for a career of civil engineering. After receiving the Bachelor of Science degree in 1877, he spent three years at the Polytechnic School at Berlin. Upon his return to the United States he assisted General Francis A. Walker in collecting hydraulic data for the Census of 1880. Soon after General Walker was chosen President of the Massachusetts Institute of Technology in 1881, Mr. Swain became an instructor in civil engineering. He remained at the Institute until 1909, having been appointed an assistant professor in 1883 and professor in 1887.

In 1909 Professor Swain accepted the Gordon McKay Professorship of Civil Engineering in the newly-formed graduate school of engineering at Harvard University. He held this appointment until his death, becoming emeritus in 1929 when illness prevented his active participation in the classroom.

Many will remember Professor Swain as a distinguished teacher. His ideas of teaching are succinctly stated in his address as President of the American Society of Civil Engineers in 1913, when he said, "Our teachers are generally, I think, chosen upon an incorrect principle; they are appointed by reason of what they know; it seems to me they should be selected for what they are—for their ability to teach and their power of enforcing scientific discipline." His many students well remember with what vehemence he enforced scientific discipline in the classroom. He placed very little emphasis on the content of his courses, mere information was relatively unimportant. The training of the mind in logical reasoning was of greatest importance. Professor Swain wrote numerous papers and several books for the advancement of technical education. For more than thirty years he had been working intermittently on a treatise on Structural Engineering. Three volumes of this great work have been published, the remaining two were left in manuscript, almost completed. In 1928, Professor Swain became the first recipient of the Lamme Medal awarded by the Society for the Promotion of Engineering Education for accomplishment in

technical teaching or actual advancement of the art of technical training.

Professor Swain also distinguished himself as an engineer and public servant. In 1887 he analyzed the causes of the Bussey Bridge disaster, whereupon he was appointed consulting engineer for the Railroad Commissioners of the Commonwealth of Massachusetts. While in this service from 1887 to 1914, he examined all existing railroad bridges and examined the designs for all proposed railroad bridges within the state. In 1894 he became a member of the Boston Transit Commission, which body designed and constructed the East Boston Tunnel under Boston Harbor and all the subways for electric railway transportation in the City of Boston. Professor Swain served continuously on this Commission until it expired on June 30, 1918, being chairman for the last four years.

He was consulting engineer for many projects, among them being design and construction of bridges, abolition of railroad grade crossings and valuation cases.

Professor Swain was an active member in many professional societies, being always willing to take his share of the burden of committee work and to promote the interests of the society. He was an honorary member of the American Society of Civil Engineers of which he was a past president, a member of the American Society of Mechanical Engineers, Institute of Civil Engineers of Great Britain, Engineering Institute of Canada, Boston Society of Civil Engineers of which he was a Past President, American Railway Engineering Association, American Society for Testing Materials, American Concrete Institute, Society for the Promotion of Engineering Education of which he was a Past President, New England Water Works Association, New England Railroad Club; a Fellow of the American Academy of Arts and Sciences and the National Academy of Sciences.

New York University awarded Professor Swain the honorary degree of Doctor of Laws in 1906 and the University of California conferred a similar honor on him in 1918.

During the three years of his last illness Professor Swain derived much enjoyment from the visits and letters of his many friends, including many former students. Of the latter he said on several occasions that he was very much pleased that so many of them turned out much better than he expected they would. He was also able to hold his interest in reading, especially biography and history.

BOOK REVIEWS

High Frequency Alternating Currents. By Knox McIlwain and J. G. Brainerd. First Edition. John Wiley & Sons, Inc., 1931. 510 pages. Price $6.00.

High frequency alternating currents phenomena are generally studied in conjunction with telephony and radio and the authors have followed this system throughout their text.

The authors have divided their book into 13 chapters. Representative problems and examples are interspersed in each chapter but it is to be regretted that there are not more of each.

The development and treatment of equivalent circuits in telephony and radio, both from the physical and mathematical standpoint is to be highly commended.

The authors have done a wonderful piece of work in their mathematical treatment of vacuum tubes when used for detection, modulation, amplification and oscillation.

The chapter on filters is very thorough and the attenuation curves of several types of filters is very enlightening.

The book assumes a faculty in the use of calculus and higher mathematics greater than that found ordinarily in the undergraduate student and thus it should find a field as a text for the graduate or as a reference book for the graduate who is interested in telephony or radio.

R. C. G.

Introduction to Vector Analysis. By L. R. Shorter, London. Macmillan and Co. xiv + 356 pages.

This volume is more a handbook or key than textbook. The treatment is a little more academic and rigorous and a little less extended in scope than either Coffin or Weatherburn. The typography is not especially pleasing or helpful to the reader.

The first chapter is devoted to the addition of vectors and includes a discussion of systems of coördinates, centroids, vector-equations, and vector and scalar point functions. Chapter II is made up wholly of unabridged solutions of forty examples illustrating the first chapter and taken largely, by permission, from Coffin's admirable text on the same subject.

The third chapter is devoted to scalar and vector "multiplication" of two or more vectors. It contains an interesting section on the division of vectors. Chapter IV, as does Chapter II, limits itself to the solutions of examples on the preceding chapter. More than fifty of the sixty-four examples are taken from Coffin.

The fifth chapter develops and extends the idea of vector differentiation and considers the algebraic aspects of gradient divergence, and cure. There is one lone section on the successive operations with Δ. Chapter VI is devoted to the solution of examples, thirty-four in number, on differentiation.

The last chapter, the seventh, deals with application to the motions of rigid bodies and to vector flow and proves Gauss's and Stokes's Theorems. There is but one short section having any direct reference to gravitational, magnetic, or electrical phenomena. No mention is made of the dyadic, so much used in physics.

K. D. S.

Principles of Electricity. By Leigh Page and Norman Ilsley Adams, Jr. First Edition. D. Van Nostrand Company, Inc., 1931. 620 pages. Price $4.25.

The authors have prepared a text consisting of 17 chapters covering the principles of electricity from the physicist standpoint as would be expected since both authors are physicists.

The first 12 chapters covers electrostatics and electromagnetism. Chapters 13 and 14 deal with A.C. currents and their measurements. Chapter 15 deals with coupled currents and filters and is a very complete chapter. Chapter 16 deals with the theory and phenomena of electromagnetic waves. Chapter 17 deals with high frequency oscillation and their measurements; this chapter is short and very elementary.

Characteristics of physicists. The authors have developed nearly all the mathematical equations by starting with the fundamental principles of physics and electricity and then developing the equations in a logical manner.

There are numerous problems and examples at the ends of most of the paragraphs.

There is considerable space devoted to the theory of electrical measurements and this is to be commended.

The text is mainly suited for physics students who are interested in electrostatics and electromagnetism, also to the more advanced physics student who wants to go a little deeper into electricity but does not wish to specialize in Electrical Engineering.